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BASIC FIELD MANUAL

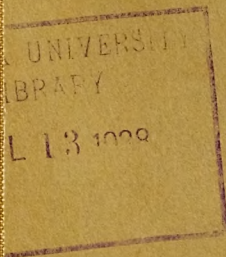


Volume I

FIELD SERVICE POCKETBOOK

CHAPTER 5

MAP AND AERIAL PHOTOGRAPH
READING



W 3.63:
vol. 1
chap. 5

BASIC FIELD MANUAL



Volume I FIELD SERVICE POCKETBOOK

CHAPTER 5 MAP AND AERIAL PHOTOGRAPH READING

**Prepared under direction of the
Chief of Engineers**



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Chapter 5, Map and Aerial Photograph Reading, Basic Field Manual, Volume I, Field Service Pocketbook, is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

MALIN CRAIG,
Chief of Staff.

OFFICIAL:

E. T. CONLEY,
Major General,
The Adjutant General.

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BASIC FIELD MANUAL, VOLUME I

FIELD SERVICE POCKETBOOK

CHAPTER 5

MAP AND AERIAL PHOTOGRAPH READING

SECTION I

GENERAL MAP INFORMATION

1. **Maps.**—*a. Classification of maps.*—(1) *Standard maps.*—Standard maps are those which, whether geographic or topographic in character, are ordinarily made in time of peace as an element of preparedness or for the economic development of the country. They are printed in quantity for general use.

(2) *Special maps.*—Special maps are those especially made for military use. Their purpose is ordinarily to show, as to a particular area, certain details not found on the standard maps thereof. Special maps may be independent surveys printed to special scales, or may be produced by drawing or printing on standard maps, or on reductions or enlargements of standard maps, the data desired to be made available.

b. Map scales.—The map scales shown in the following table have been adopted for use by the military forces. In general for a given purpose the map of smallest scale which will show the necessary detail should be selected by the prospective user.

2. **Government mapping agencies.**—In addition to the maps described in paragraph 1, which are published by the War Department and by the United States Geological Survey and which have been adopted as standard for use of the military forces, maps are issued by various Government agencies as follows:

a. Soil survey maps.—These maps are published by the Department of Agriculture on the scale of 1 inch equals 1 mile. They show roads, drainage, towns, and, by symbols and colors, the various classes of soils within the area.

(1)

Scale	Approximate inches to the mile	Classification	Sheet size	Size of area	Contour interval
1:5,000.....	12 inches=1 mile.	Special.....	Varies.....	Varies.....	5 feet.....
1:10,000.....	6 inches=1 mile.	do.....	do.....	do.....	10 feet.....
1:20,000.....	3 inches=1 mile.	Terrain.....	do.....	5' and 7½' latitude and longitude (12,000 by 20,000 yards maximum).	20 feet.....
1:62,500.....	1 inch=1 mile.	Tactical.....	Maximum 19 by 22 inches (maximum impression 18 by 21 inches).	15' latitude and longitude (25,000 by 30,000 yards).	do.....
1:500,000.....	1 inch=8 miles.	Strategic.....		4° latitude and longitude (215 by 280 miles).	100-1,000 feet (contours seldom shown).
1:500,000.....	1 inch=8 miles.	Air navigation.	Variable..	Strip of ground between airports about 80 miles in width.	Elevations shown by color gradients.
Maps of smaller scale as follows: 1:1,000,000..... 1:2,500,000..... 1:7,000,000..... 1:11,000,000..... 1:16,000,000.....	{.....}		{General and geographic.}	{Desk and wall.}	{Larger scale—States; smaller scale—United States.}
					{Contours not shown.}

Use	Natural features shown	Works of man shown	Remarks
Military studies for engineering construction.	Drainage, bodies of water and all other topographical features which may be indicated to scale. Forested areas and cultivated areas often shown by conventional signs, type of growth, etc.	All works of man of sufficient importance or size to indicate railroads, roads, bridges, dams, towns, buildings, quarries, transmission and pipe lines, mines, wells, telegraph lines, fence lines, etc.	Not standard issue.
For area or position sketches; maps for engineering construction.	Same as 1:5,000 except as affected by the reduction in scale.	Same as 1:5,000 except as affected by the reduction in scale.	Do.
For classroom in conference and map problem.	Same as 1:10,000 except as affected by the reduction in scale. Types of vegetation, cultivation, etc., seldom indicated.	Same as 1:10,000 except as affected by the reduction in scale.	1,000-yard military grid lines overprinted.
For general use.	Considerably less than 1:20,000. Generally only drainage systems, water, forested areas, etc.	Much less than 1:20,000. Does not show fence, telegraph, or pipe lines, etc.	5,000-yard military grid lines overprinted.
For large units.	Drainage systems, water, and mountain ranges.	Cities, rail lines, and terminals, maintained water and airways and terminals, and roads of military importance.	
For aerial navigation.	-----do-----	Features on the ground easily discernible from high altitudes are emphasized and other features subordinated or omitted. Special symbols are employed. In addition to features listed above, airway light and radio beacons, transmission lines, prohibited areas, etc., are shown.	Published in two editions, an Air Corps edition on special paper suitable for aerial use and a general edition for terrestrial use.
-----do-----	-----do-----	{States and principal cities.	{Published by the U. S. Geological survey.

b. Post route maps.—These maps are made by the Post Office Department for the designation of postal routes and are primarily for internal administration in that department.

c. Coast and Geodetic Survey charts.—These charts are intended for the use of navigators on the coast and are published on various scales ranging from 1:5,000 to 1:40,000 for harbor charts and from 1:80,000 to 1:100,000 for coast charts. They show the depth of the water, aids to navigation, and a narrow strip of topography from 1 to 5 miles in width along the shores.

d. Lake survey charts.—These charts are intended for the use of navigators on the Great Lakes and adjacent waters and are published on various scales ranging from 1:5,000 for small harbors to 1:1,200,000 for the general chart of all the lakes. The charts likewise show the depth of the water, aids to navigation, and a narrow strip of topography from 1 to 5 miles in width along the shores.

e. General Land Office maps.—Maps of this bureau are comprised of the following: *Township plots* showing land division and area of tracts; *maps of States* having public land showing land survey lines and United States reservations; *general maps of the United States* showing sources of obtaining land, civil and public land boundaries, and progress of land surveys.

f. International Boundary Commission: United States and Canada.—These maps cover a strip of territory from $\frac{1}{2}$ to $2\frac{1}{2}$ miles in width on each side of the boundary between the United States and Canada, from the Arctic Ocean to Mount St. Elias, from the Pacific Ocean to Lake Superior, and from the head of the St. Lawrence River to the Atlantic Ocean. From Mount St. Elias to Cape Muzon the boundary maps include practically all the territory between the boundary line and the Pacific Ocean. The scales used are: 1:6,000, 1:12,000, 1:24,000, 1:62,500, and 1:250,000, depending on the locality. The contour intervals range from 5 to 250 feet and the maps are complete in cultural features and relief.

g. United States Forest Service maps.—The United States Forest Service prepares maps of areas included within the national forest boundaries and adjacent thereto. The maps are compiled from all sources, governmental and private, supplemented by United States Forest Service surveys. They are

intended primarily for administrative purposes in the United States Forest Service. Besides the topography and culture they frequently carry detailed classification of vegetation. The publication scales are $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, and 1 inch to the mile.

3. Map distribution.—The allowances of military maps are as follows:

a. General maps.—(1) *Regular.*—One copy per headquarters component shown in Tables of Organization of each organization considered down to and including the battalion or similar unit.

(2) *Exception.*—Organizations covered by special allowances.

b. Strategic maps.—(1) *Regular.*—(a) One copy per commissioned and warrant officer of each headquarters shown in Tables of Organization down to and including the battalion or similar unit.

(b) One copy per organization assigned a Table of Organization down to and including the battalion or similar unit.

(c) One copy per section of division, brigade, regimental, and battalion staffs.

(2) *Exceptions.*—(a) For the Cavalry the allowance will be increased by 50 percent.

(b) For the Air Corps the allowance for air navigation maps will govern.

c. Air navigation maps.—The allowance of air navigation maps for the Air Corps is based on—

25 to General Headquarters Air Force.

100 to division headquarters (air section).

10 to each wing headquarters.

10 to each group headquarters.

4 to each squadron headquarters.

4 per airplane.

d. Tactical maps.—(1) *Regular.*—(a) One copy per commissioned and warrant officer.

(b) One copy per each component shown in Tables of Organization of each organization considered down to and including the company or similar unit.

(c) One copy per section of division, brigade, regimental, and battalion staffs.

(2) *Exceptions.*—(a) In computing map allowances for the Air Corps, enlisted pilots will count as officers.

(b) 100 to division staff (air section).

NOTE.—Division headquarters (or, in the case of smaller expeditions acting independently, the headquarters thereof) will normally be allowed an additional quantity of each map equal to 50 percent of the initial distribution provided above, normally to be in custody of the division or detachment engineer, to be issued as required prior to the reproduction of maps in the field.

4. Accuracy of maps.—Standard maps are prepared with the objective of attaining no errors which are appreciable at the scale of the maps, i. e., for maps of 1:62,500 scale the minimum appreciable error is about 60 feet. The allowable discrepancy in contour elevations is not greater than one-half the contour interval. Special maps, because of time and space factors, may be prepared with an expectancy of greater discrepancies. Even an accurate map may soon become out of date because of works of man. The map reader should appraise the accuracy of his map and, if necessary, supplement it by recent aerial photographs if he has reasons to believe that changes in topographic detail so warrant.

5. Marginal information.—Before using a map, the reader should first examine it with a view to determining what it represents. All or part of the data listed below are usually printed on the margins of maps in order to convey this information. They are illustrated on the standard map sheet form represented in figure 1, the reference numbers shown in the figure corresponding to the item numbers listed below:

① Harriman index number of the map and the location in the Harriman index of the quadrangle shown on the map sheet. Directions concerning the use of the Harriman index system are contained in TR 190-7.

② Name of the State or States within which the area mapped lies and the name of the quadrangle or area.

③ Its scale.

④ Its orientation with the local magnetic declination and gisement.

⑤ Explanation of symbols which have not been adopted as standard.

⑥ The contour interval.

⑦ Name of the organization which issued the map.

⑧ The date of issue or revision.

⑨ The names of the organizations executing the surveys and topography upon which the map is based and the date of

their execution. If compiled, the source of compilation is also shown.

- ⑩ The projection used.
- ⑪ The horizontal datum.
- ⑫ The vertical datum.
- ⑬ The zone of the military grid.
- ⑭ If in the overlap of two zones, a reference to the grid of the second zone.
- ⑮ The designations of the geographic grid lines.
- ⑯ The designations of the military grid lines.
- ⑰ The names of adjoining map sheets.
- ⑱ An index of the adjoining map sheets (sometimes shown).
- ⑲ The filing name.

6. Conventional signs.—Standard abbreviations, both general and military, for maps and standard map symbols, both military and topographic, are contained in chapter 6, BFM, volume I.

7. Military grid system.—For the purposes of superimposing on maps a rectangular grid, the United States has been divided into zones, designated by letters from A through G, each zone being 9° of latitude in width. This rectangular grid is fitted over the polyconic projections of each zone, i. e., the north-south line of the grid coincides with the central meridian of the zone. The following table shows the designation of the several zones across the United States, their central meridians, their limiting meridians, their origins of coordinates, and the grid coordinates assigned to each origin:

Zones of the military grid

Zone	Central meridian	Limiting meridians	Origin of coordinates		Grid coordinates of the origin	
			Latitude	Longitude	X yards	Y yards
A.....	73°	68°30' - 77°30'...	40°30' N...	73° W...	1, 000, 000	2, 000, 000
B.....	81°	76°30' - 85°30'...	40°30' N...	81° W...	1, 000, 000	2, 000, 000
C.....	89°	84°30' - 93°30'...	40°30' N...	89° W...	1, 000, 000	2, 000, 000
D.....	97°	92°30' - 101°30'...	40°30' N...	97° W...	1, 000, 000	2, 000, 000
E.....	105°	100°30' - 109°30'...	40°30' N...	105° W...	1, 000, 000	2, 000, 000
F.....	113°	108°30' - 117°30'...	40°30' N...	113° W...	1, 000, 000	2, 000, 000
G.....	121°	116°30' - 125°30'...	40°30' N...	121° W...	1, 000, 000	2, 000, 000

That part of Maine to the eastward of longitude $68^{\circ}30'$ is included in the grid for zone A. Figures 2 and 3 illustrate respectively the arrangement of grid zones for the United States

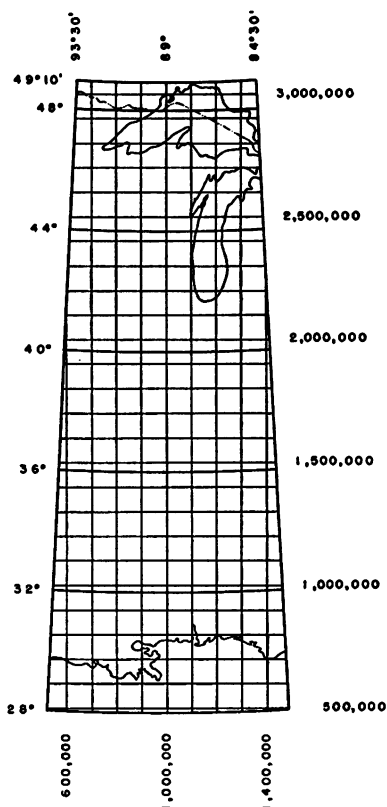


FIGURE 3.—Special military map of grid zone C.

and the superposition of the 100,000-yard grid lines upon the area forming grid zone C.

8. **Grid variations.**—Because of the convergence of the meridians there is a variation between true north and grid north

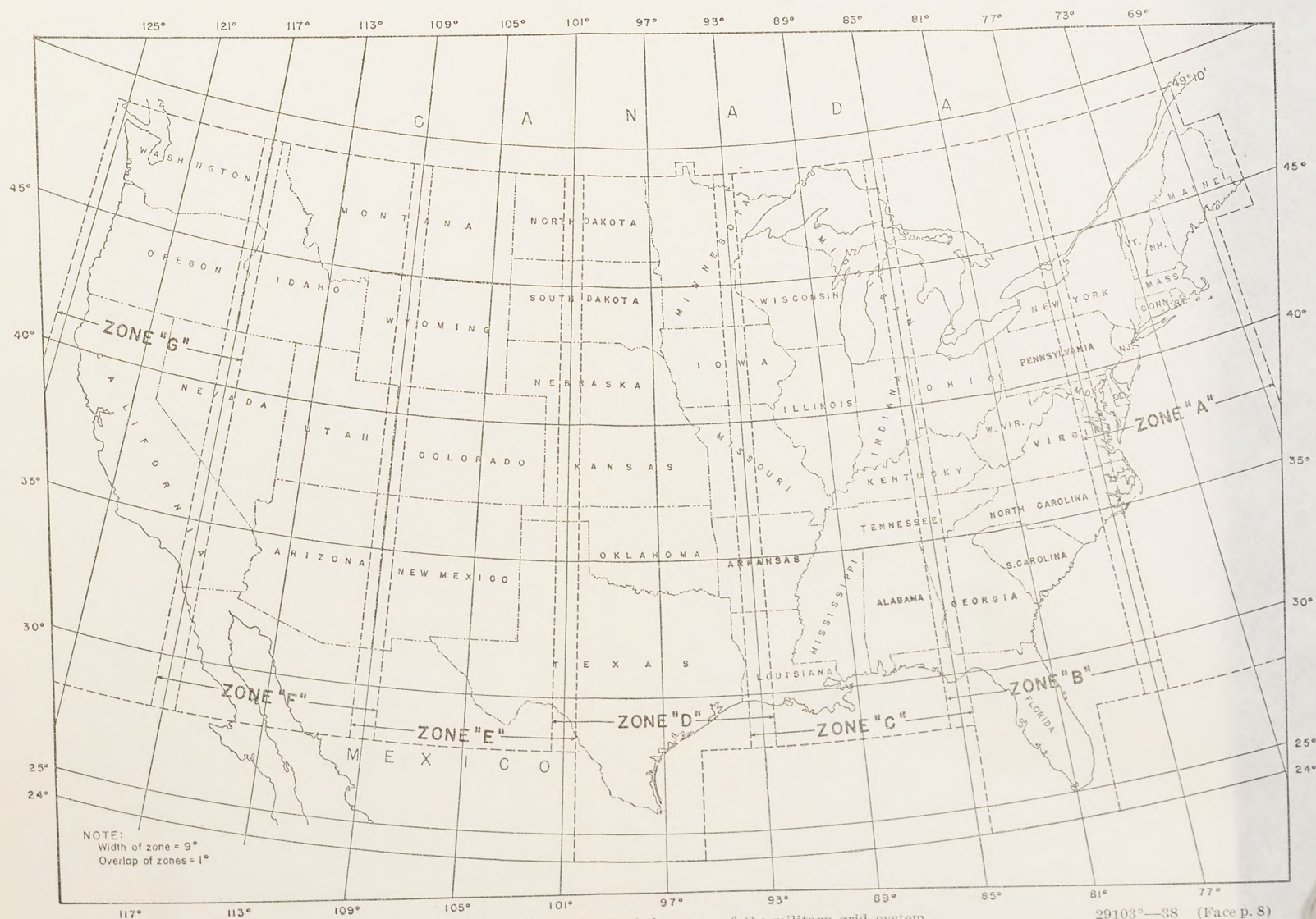


FIGURE 2.—Designation of the zones of the military grid system.



except on the central meridian of the grid zone. This deviation of grid north from true north reaches a maximum of more than 3° at the edge of the grid zone. Because of the magnification of scale in a north-south direction incident to the polyconic projection, there is also a discrepancy in distance measurement in this direction which increases as one departs from the central meridian and approximates two-tenths of 1 percent at the outer edge of the zone. This scale error is of no military consequence as it is exceeded by the changes in dimension of the ordinary paper map sheet due to climatic conditions.

SECTION II

ORIENTATION AND LOCATION

9. **General.**—In using a map in the field, the first step in map reading is the orientation of the map, i. e., all lines on the map are brought parallel to the same lines on the ground. The second step is the determination of one's position which means the orientation of oneself.

10. **North.**—*a. General* (fig. 4).—All complete maps have the meridians of true north, grid north, and magnetic north indicated.

b. True north.—True north means the direction of the North Pole from the observer. Since all true north meridians converge inward toward the geographic north pole, the true meridian at any one point normally will not be parallel to the true meridian at another point east or west of it.

c. Grid north (fig. 3).—Grid north is the direction in which the north-south grid lines point. All north-south grid lines of the same zone are parallel to one another, their direction being determined by the true meridian at the center of the grid zone.

d. Magnetic north.—Magnetic north is the direction in which the compass needle points when unaffected by any local attraction. This gives the direction of the magnetic north pole. Since the position of this magnetic pole changes from year to year, the direction of magnetic north not only varies from place to place but also varies at any one place from year to year.

11. **Compass variations.**—*a. Declination.*—The angle between the magnetic and the true meridians at any place is called the

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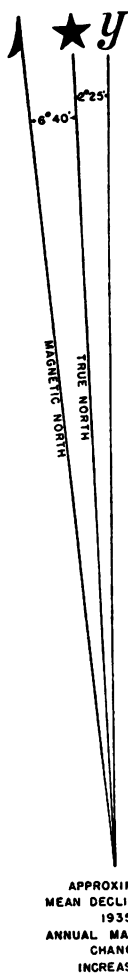
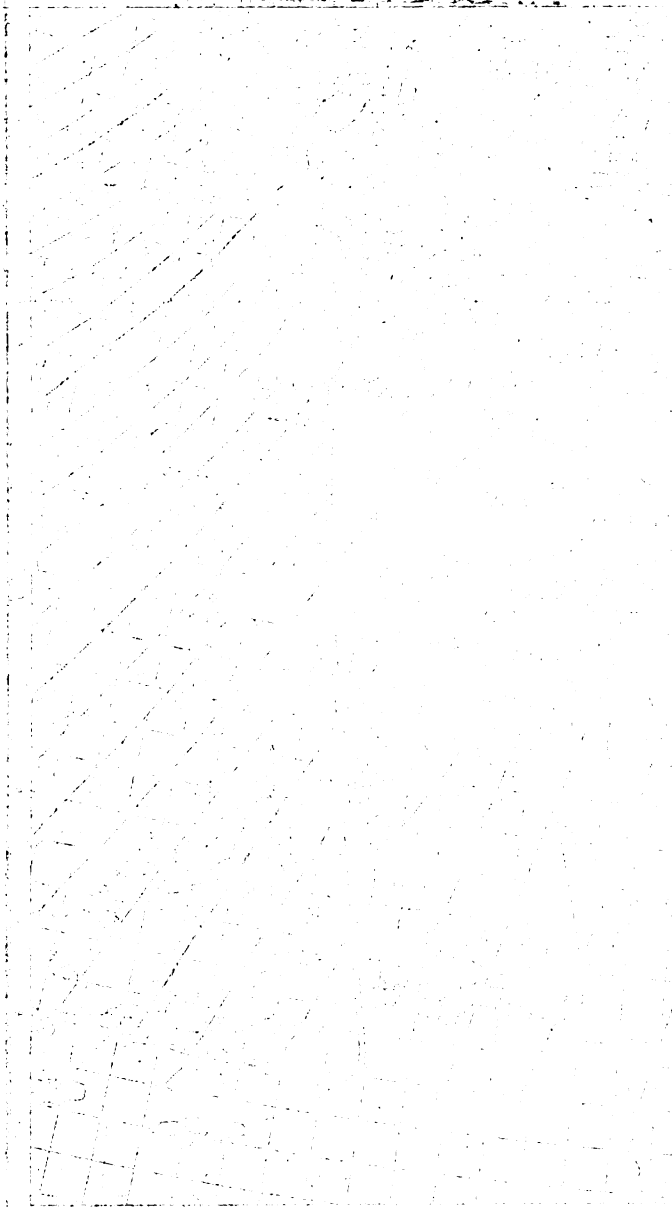
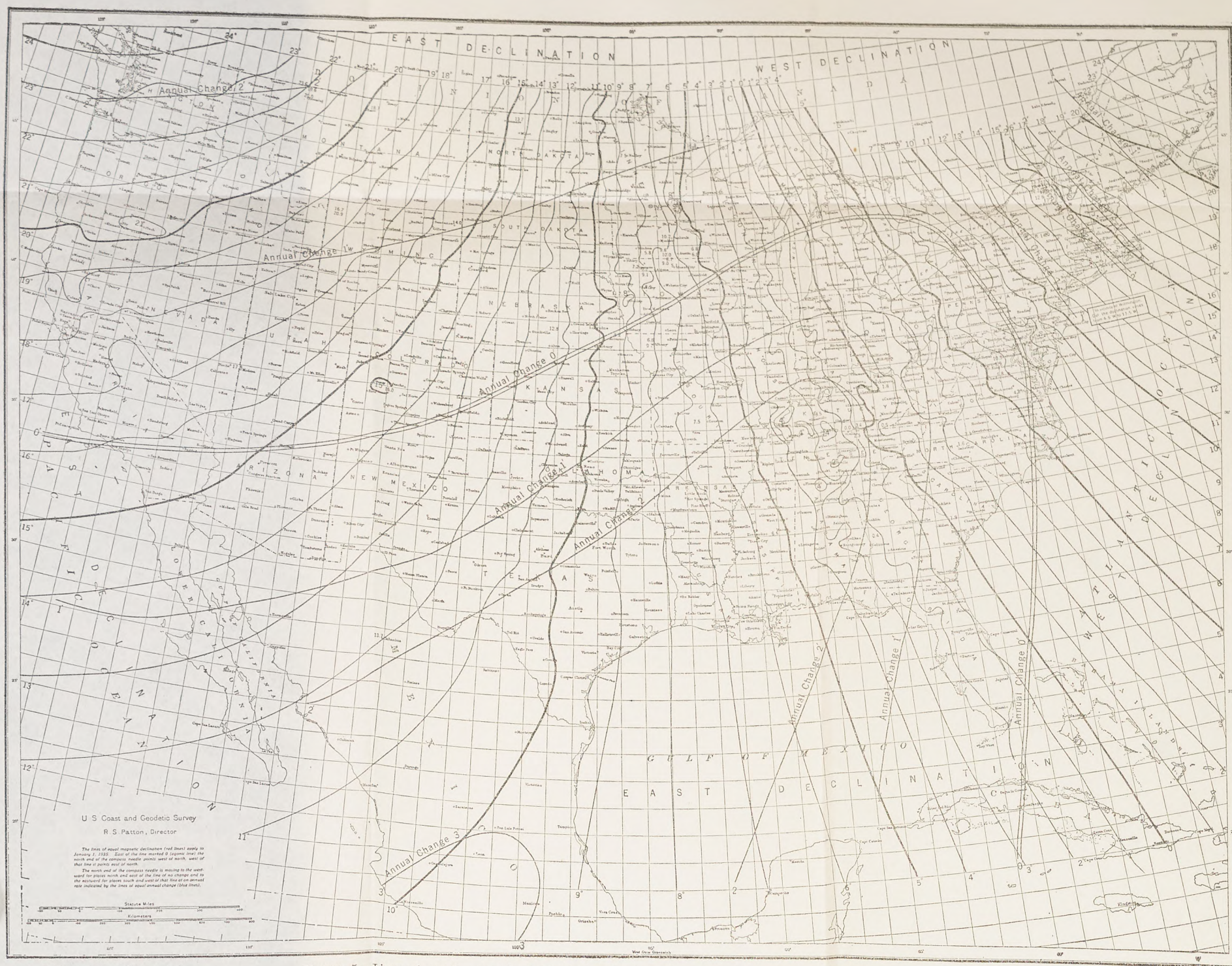


FIGURE 4.—True north, magnetic variation, and grid variation (or gisement) as indicated on the margin of maps.





declination of the needle for that place. Figure 5 is an isogonic chart showing the variation of the compass at different parts of the United States for the year 1935. Isogonic lines are lines joining points of the same magnetic declination. The magnetic declination for a map having the magnetic meridian indicated as in figure 4 is computed as follows:

Example: The magnetic declination for the year 1940 is desired for use with the map. The approximate mean declination for the year 1935 is $6^{\circ}40'$ W. The annual magnetic change is $3'$, increasing. The increase in 5 years (1940) is $5 \times 3'$ or $15'$. Consequently the magnetic declination for the year 1940 is $6^{\circ}55'$ W.

b. Local attraction.—Presence of iron and electric fields of magnetism affect a compass and great care should be taken not to approach them within a distance which will cause the compass needle to deviate while making an observation. The following are the minimum safe distances for *visible* masses of iron and electric fields of magnetism:

	Yards
High tension power lines-----	150
Heavy gun-----	60
Field gun and telegraph wires-----	40
Barbed wire-----	10
Steel helmet -----	3

Gas masks, firearms, etc., also affect the compass needle.

12. Determination of true north by field expedients.—*a. By aid of a watch and the sun* (fig. 6).—North can be determined

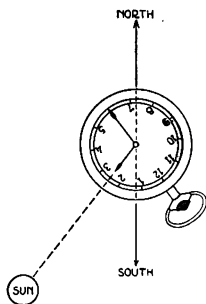


FIGURE 6.—Determination of north by watch and sun.

with an error of less than 8° if the sun is visible and a watch showing approximately the correct sun time is available. Point the hour hand, watch held face up, at the sun. This is facilitated by casting the shadow of a vertical pencil across the face of the watch and by then bringing the hour hand into this shadow. A line drawn from the center of the dial to a point halfway on the smaller arc between the hour hand and the 12 of the watch will point south. In the Southern Hemisphere the watch must be held face down and this line will point north. This method is difficult to use when the sun is very high in the heavens and is of no use in the Tropics.

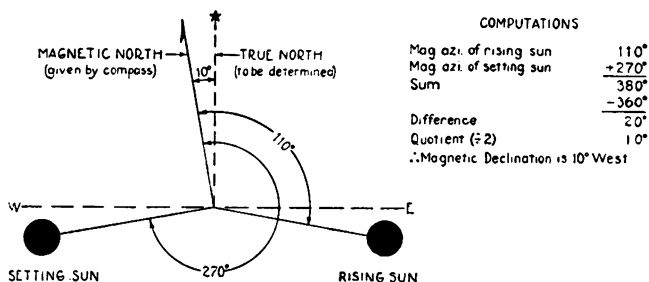


FIGURE 7.—Determination of north by the rising and the setting of the sun.

*b. By the rising and setting of a celestial body (fig. 7).—*Observe the magnetic azimuth of the sun, a planet, or a bright star at rising and setting on the same day or at setting on one day and rising the next. Add these two azimuths together. Take the difference between this sum and 360° . One-half of this difference is the declination of your compass—east, if the sum of the azimuths is less than 360° ; west, if it is greater. In using this method the observations are best taken when the object is just above the true horizon, or at a gradient of zero. This can usually be done if a high point is chosen for observation. If this cannot be done, be careful to take both observations with the object at the same gradient, as determined with a clinometer. This is most important with the sun. Under the least favorable conditions an inequality of 1° in the gradients at the time of observation on the sun may

introduce an error of $\frac{1}{2}^\circ$ in the result. In using a star, choose one which rises nearly east from the point of observation. If this is done the inequality of a degree in the gradients will be immaterial. Both observations need not be made at the same point, but should not be more than 10 miles apart in east and west or north and south directions.

c. *By aid of the sun and a plumb line* (fig. 8.)—On a level piece of ground lean a pole toward the north and rest it in a crotch made by two sticks as shown. Suspend a weight from the end of the pole so that it nearly touches the ground; then, about an hour before noon, attach a string to a peg driven

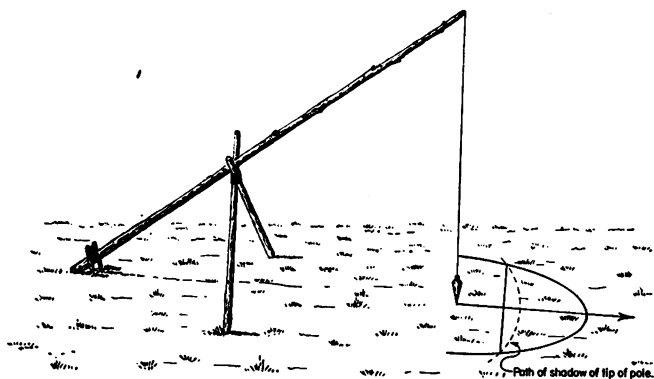


FIGURE 8.—North by sun and plumb line.

directly under the weight and, with a sharpened stick attached to the other end of the string, describe an arc with a radius equal to the distance from the peg to the shadow of the tip of the pole. Drive a peg on the arc where the shadow of the tip of the pole rested. About an hour after noon, watch the shadow of the tip as it approaches the eastern side of the arc and drive another peg where it crosses. By means of a tape or string, find the middle point of the straight line joining the last two pegs mentioned. A straight line joining this middle point and the peg under the weight will be in the true meridian.

*d. By means of the North Star (Polaris).—*Ursa Major (called the Big Dipper) shown in the upper portion of figure 9 is the easiest constellation to distinguish and provides the best means for locating the North Star. The two "pointers," or the stars forming the lip of the dipper, point to the North Star (Polaris) at all times as the Dipper appears to circle the pole. On the opposite side of Polaris and at about the same distance from it

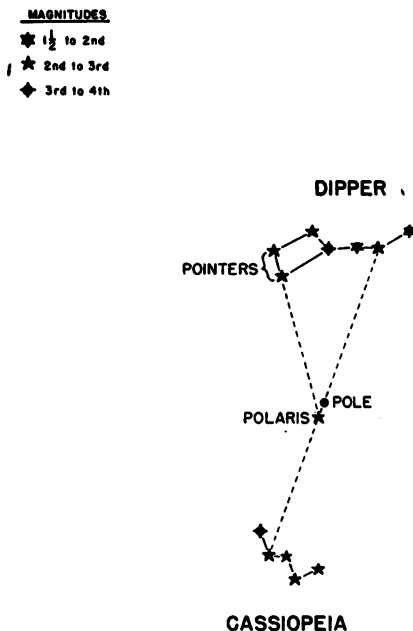


FIGURE 9.—Determination of north by the North Star.

is the constellation of Cassiopeia. Its form is that of the letter "W." The great importance which attaches to the North Star is that it is never more than 2° away from the point where the axis of the earth, if extended, would pierce the heavens. It therefore appears to the eye to be always in the same place. An observation of the North Star to determine true north, when the Dipper and Cassiopeia are above and

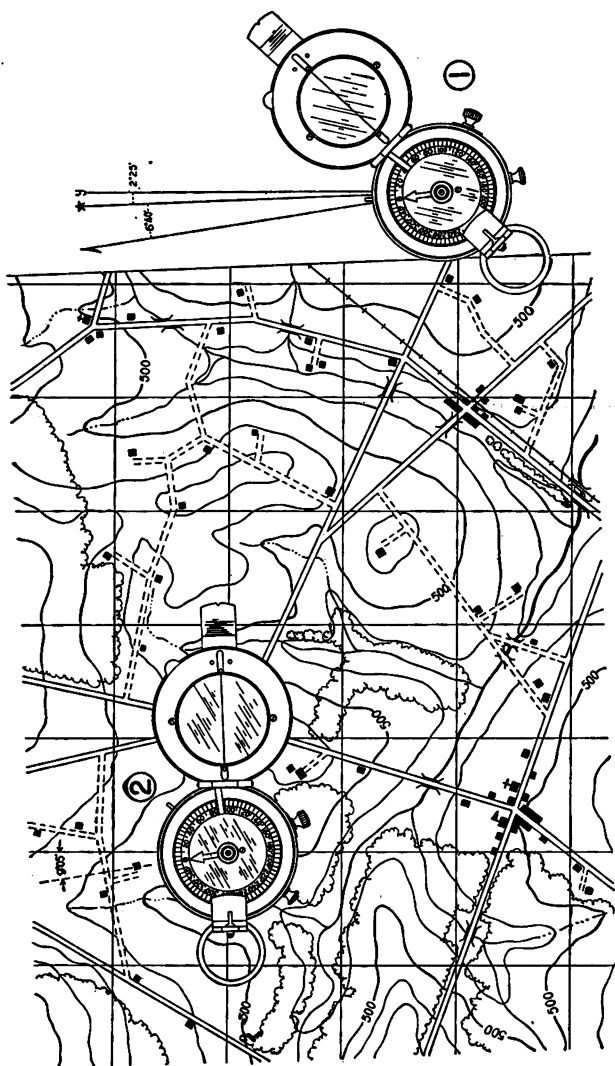


FIGURE 10.—Orientation of the map by means of a compass.

below the North Star, will give the declination of the compass to within the least reading of the compass.

13. Orientation of the map.—*a. By means of a compass when magnetic north is indicated (fig. 10 ①).*—Place the map on a level surface. Lay the compass, opened, over the magnetic north meridian (extended if necessary) printed in the margin of the map sheet with the north point of the compass case pointing magnetic north on the map, line of sight along the axis of the case (etched line or markers) in coincidence with the magnetic meridian. Revolve the map and compass together until the needle points magnetic north.

b. By means of a compass when the map does not show the magnetic meridian (fig. 10 ②).—The compass is placed on the

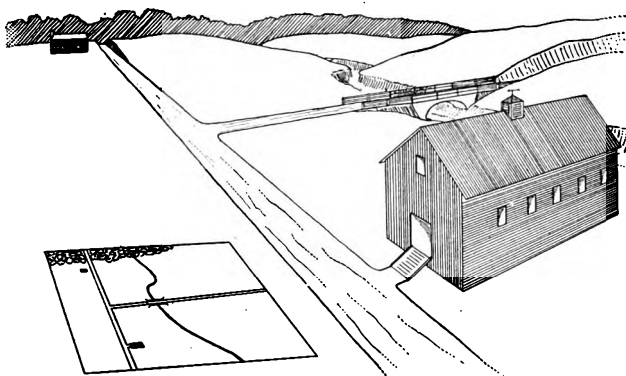


FIGURE 11.—Orientation of the map by inspection.

map as in *a* above but alined with the true north meridian or the grid north meridian, whichever may be the more convenient. The map is then revolved until the compass needle reads on the azimuth circle the local magnetic declination from true or grid north, respectively.

c. By inspection (fig. 11).—(1) Carefully observe the road system or ground features in the immediate vicinity.

(2) Identify the corresponding conventional signs on the map.

(3) Hold the map horizontally and turn about until the road system on the ground parallels the road system on the map, or

until the positions of the observed ground features appear in similar relation to the positions of their corresponding conventional signs on the map. The map is now oriented. This method should be used when practicable.

d. By means of a single distant point when one's position is known (fig. 12).—(1) Identify a distant object identifiable on the map.

(2) Draw a line through your map position and the conventional sign representing the object.

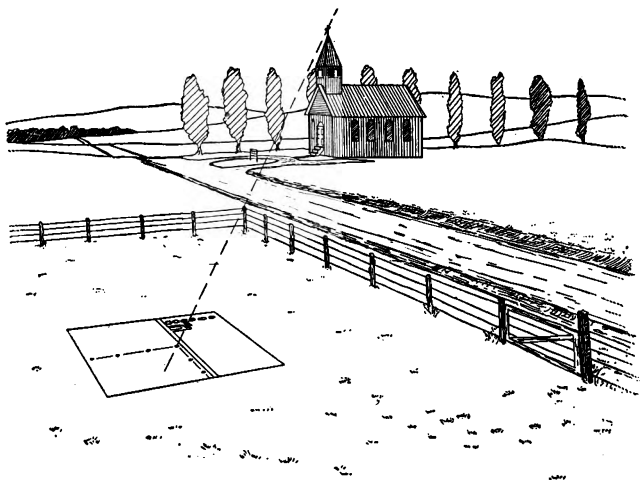


FIGURE 12.—Orientation of the map by means of a distant point.

(3) Turn the map so that the line drawn on the map points in the direction of the distant object.

14. Determination of one's position on an oriented map.—
a. By traverse from a single known point (fig. 13).—(1) Select the nearest visible object on the terrain such as *A* identifiable on the map at *a*.

(2) Rest the map in a horizontal position on a convenient support from which *A* is visible and set a pin in the map at *a*.

(3) Orient the map by compass or by inspection.

(4) Holding a straightedge against the pin through *a*, align its edge with the object *A* on the terrain.

(5) Draw in lightly a line along the straightedge through *a* and extending in the direction of your position.

(6) Stride or estimate the distance on the ground from your position to *A*.

(7) Plot along the line through *a* to scale on the map the strided or estimated distance *aO* to give *O*, your map location.

b. By resection from two known points (fig. 14).—(1) Select two visible objects of the terrain, as *A* and *B*, identifiable at *a* and *b* on the map and so situated that lines radiating from

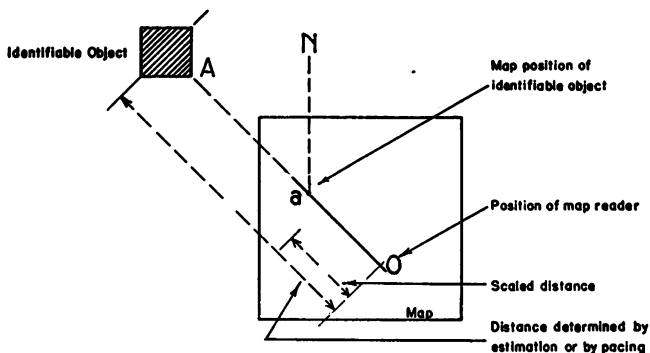


FIGURE 13.—Determination of one's position on a map by traverse.

the observer to the objects form a good angle of intersection at the observer.

(2) Rest the map in a horizontal position on some nearby convenient support, such as a fence post, stone, or convenient fold in the terrain, from which the objects *A* and *B* on the terrain are visible, and set pins through their respective map positions *a* and *b*.

(3) In this position, orient the map by compass or inspection.

(4) Sight on *A* and *B* successively along a straightedge held against the pins through the corresponding points *a* and *b*, respectively, on the map. Along the straightedge strike in the respective direction lines *aA* and *bB*. Prolong these lines to intersect at *O*, which is the point sought.

c. By either of the above methods when one's position is along a road (fig. 15).—(1) Identify a convenient visible object A on the ground identifiable on the map at a.

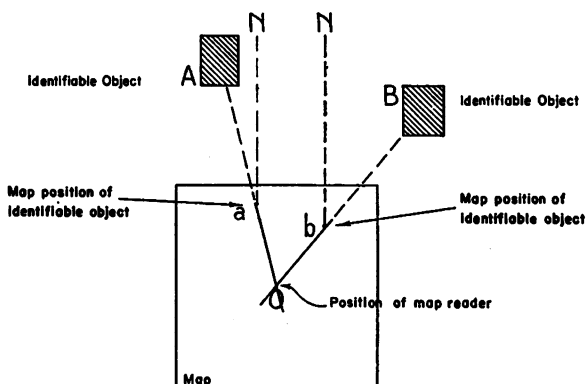


FIGURE 14.—Determination of one's position on a map by resection.

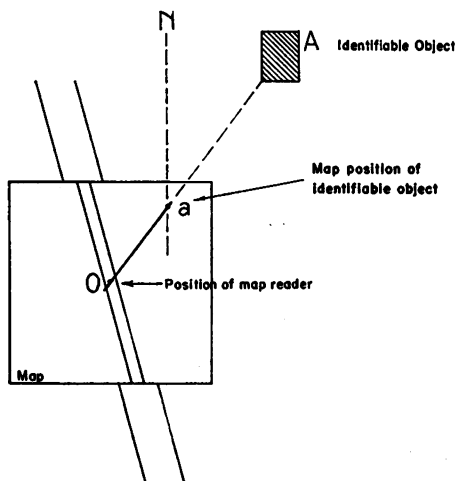


FIGURE 15.—Determination on a map of one's position along a road.

(2) Rest the map in a horizontal position on some nearby convenient support such as a fence post, stone, or fold in the terrain from which *A* is visible, and set a pin in the map at *a*.

(3) Orient the map by compass or by inspection.

(4) Holding a straightedge against the pin through *a* on the map, aline its edge with the object *A* on the terrain.

(5) Strike in lightly the line *aA* along the straightedge and prolong to intersect with the road at *O*, which is the point sought.

15. Determination of one's position on an unoriented map by three-point resection (tracing paper method).—*a*. (Fig. 16 ①.) Select three visible objects on the terrain such as *A*, *B*, and *C*, identifiable on the map at *a*, *b*, and *c*, respectively, and so distributed that radial lines drawn from observer to each point will yield good angles of intersection at the approximate position of the observer.

b. Place a small piece of tracing paper on a field message book or other flat surface supported on a convenient fence post, rock, or on the ground, and set a pin in it at an assumed position of the observer at *O*.

c. (Fig. 16 ②.) Place the rectangular protractor or any suitable straightedge against the pin, sight along its edge successively to each object (*A*, *B*, and *C*) on the terrain, and draw radial lines against the straightedge toward each object.

d. (Fig. 16 ③.) Remove the tracing paper and superimpose it over the map, shifting it about until the three radial lines pass through the conventional signs *a*, *b*, and *c* on the map which correspond to the three objects sighted on the ground.

e. In this position prick through to the map at the intersection or origin of the lines the position of the observer *O* sought. This method is useful on unoriented maps, when the observer is without a compass in indefinite terrain of which only distant prominent features are recognizable, or when local attraction due to presence of ore bodies renders the magnetic needle useless.

16. To locate on a map a distant or inaccessible object (intersection).—The observer occupies in succession the positions *A* and *B* on the ground. In each position he rests the map horizontally on some nearby convenient support and sets a pin in the corresponding map position *a* or *b*. In this position the

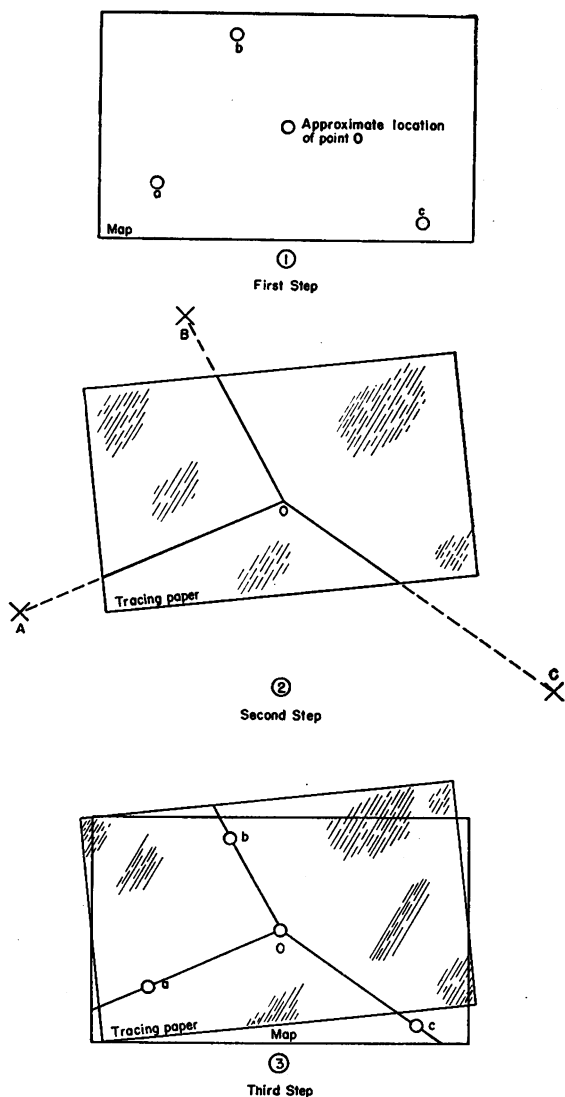


FIGURE 16.—Determination of one's position on a map by three-point resection (tracing paper method).

map may be oriented with a compass, by inspection, or by aligning the positions *a* and *b* on the map with the corresponding objects *A* and *B* on the ground. At each occupied position a straightedge is placed against the pin in the corresponding position on the oriented map; the object *C* on the terrain whose position is sought is sighted along the straightedge and a direction line drawn thereto. This results in two such direction lines to the object, one from each occupied position, the intersection of which gives the map position *c* of the object sought.

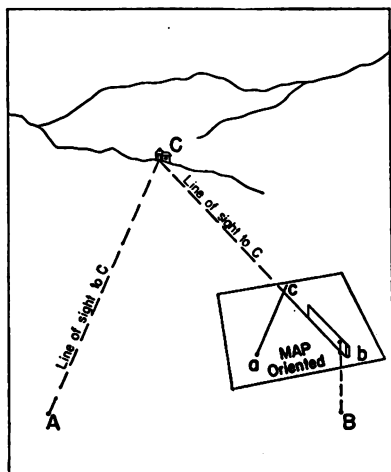


FIGURE 17.—Determination of the location on a map of a distant object by intersection.

17. Coordinate systems.—The characteristics of the commonly used coordinate systems are given in the table on pages 24 and 25.

18. Polar coordinates.—Figure 18 illustrates the designation of the position of a point *b* the polar coordinates of which are BM 38, Accotink (village), distance 1,800 yards, on grid azimuth $23^{\circ}30'$. The base position BM 38 is marked *a*, the distance from the base position to the designated point *b* is the line *ab*, the base direction grid north is *ay*, and the angle from the base direction is *yab*.

19. Rectangular coordinates.—Figure 19 illustrates the designation of the position of a point *d* the rectangular coordinates of which are BM 38, Accotink (village), 1,500 yards east (magnetic), 1,100 yards north (magnetic). The base position

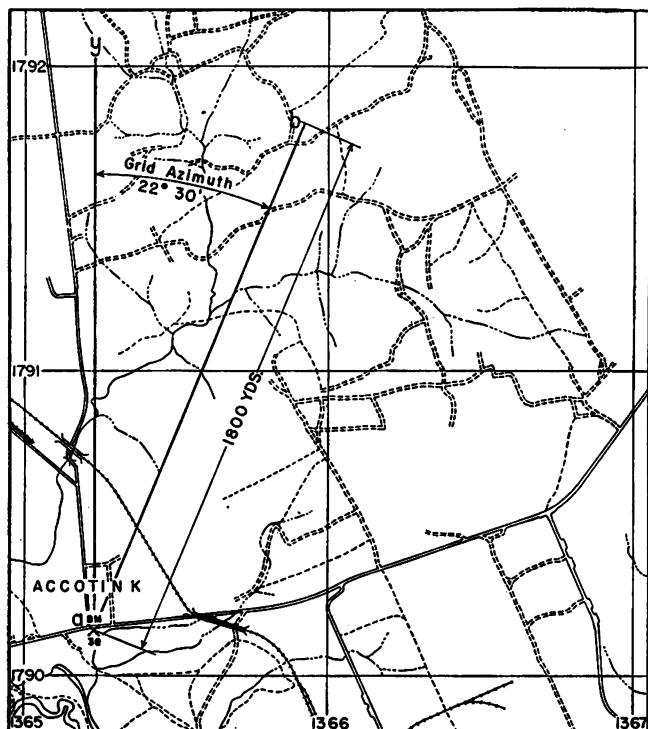


FIGURE 18.—Polar coordinates, BM 38, Accotink (village), distance 1,800 yards, on grid azimuth $22^{\circ}30'$.

BM 38 is marked *a*, the base direction magnetic north is *am*, and the respective distances are *ab* and *ac*.

20. Geographic coordinates.—Figure 20 illustrates the designation of the position of a point *a* the geographic coordinates of which are latitude $38^{\circ}42'20''$ N., longitude $77^{\circ}13'30''$ W.

Coordinate

Name	Character	Elements	Base position	Base directions
Polar coordinates.	Relative.	1. Base position. 2. Distance from base position. 3. Base direction. 4. Angle from base direction.	Fixed landmark, survey monument, or other position easily identified on the ground.	True, magnetic, or grid north (or south). In map reading always assumed to be true north unless otherwise stated.
Rectangular coordinates.	---do----	1. Base position. 2. Base direction. 3. Two distances measured at right angles from the base position.	Landmark, survey monument, or well established position.	True, magnetic, or grid north. Assumed to be true north unless otherwise stated.
Geographic coordinates.	Absolute.	1. Standardized base position. 2. Two distances from base position conforming to geographic grid formed by meridians of longitude and parallels of latitude.	Intersection of meridian of Greenwich with the Equator.	True north....
Grid coordinates.	---do----	1. Zones conforming to polyconic projection. 2. Standardized base position. 3. Two distances from base position conforming to the military grid.	Point 1,000,000 yards west and 2,000,000 yards south of intersection of central meridian of zone with parallel of latitude 40°30' N.	Grid north....

systems

Measurements	Use	Example
1. Distance measured on ground in feet, yards, or miles. 2. Angles from base directions as azimuths or bearings.	To locate points with compass in field and corresponding position on map with protractor.	1. Walla Walla Quad. U. S. G. S., 1:62,500, BM 1224 on main road 2 miles westerly from Wabburg, S. 22°45' W, 4.62 miles. 2. Terrain map, Fort Belvoir and vicinity 1:20,000 (1935), BM 38, Accotink (village), distance 500 yards on grid azimuth 330°. 3. Terrain map, Fort Belvoir and vicinity 1:20,000 (1935), Woodlawn School, distance 1,800 yards on a magnetic azimuth 22°30'.
Distance measured on ground in feet, yards, or miles.	To locate points without the aid of a protractor.	Terrain map, Fort Belvoir and vicinity, 1:20,000 (1935), BM 38, Accotink (village), 1,500 yards east (magnetic), 1,100 yards north (magnetic).
In degrees, minutes, and seconds of arc. In special instances also expressed in degrees and minutes of arc and meters. The units of arc at different points on the earth vary in length when expressed in units of length.	To express position of large indefinite areas, in unmapped areas, or on maps which do not contain the military grid but show meridians of longitude and parallels of latitude.	1. Latitude 38°42'20" N, longitude 77°13'30" W.
In thousands of yards, the distance east of the base position (X coordinate) being written first and, with a dash between, being followed by the distance north of the base position (Y coordinate), the whole being inclosed in parentheses.	To express position of point on maps on which military grid is printed.	1. "Grid zone B" (1,359.592-1,787.383).

The geographic grid has been drawn on the map by joining the registration ticks indicating its position. On a terrain sheet (fig. 20) 1-minute (60 seconds by 60 seconds) quadrangles are formed. On a tactical sheet 5-minute quadrangles (300 seconds

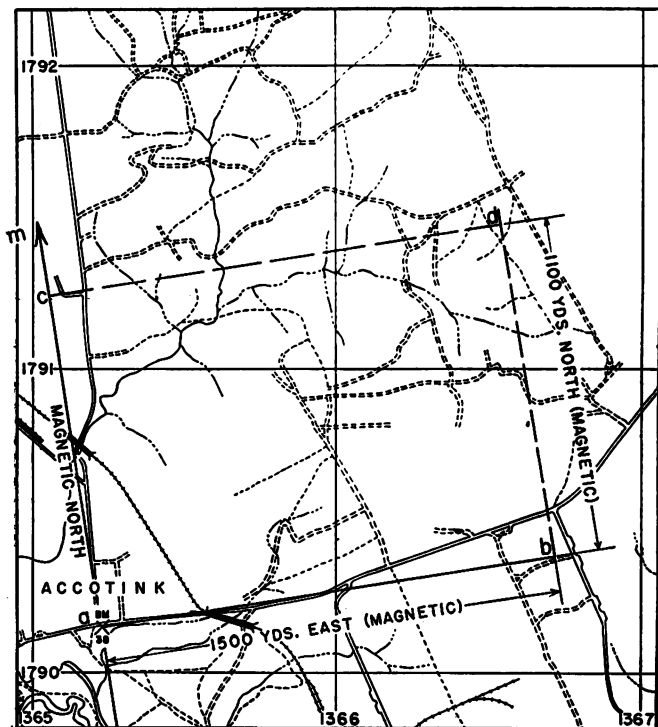


FIGURE 19.—Rectangular coordinates, BM 38, Accotink (village), 1,500 yards east magnetic, 1,100 yards north magnetic.

by 300 seconds) are formed. By inspection it is readily determined that the point falls somewhere between the geographic grid lines $38^{\circ}42'$ and $38^{\circ}43'$ of latitude and somewhere between the geographic grid lines $77^{\circ}13'$ and $77^{\circ}14'$ of longitude. The engineer scale or any other suitably graduated scale may

be used conveniently as a scale of proportional parts to plot the point within the quadrilateral formed by the 1-minute geographic grid. To do this, place the scale diagonally anywhere

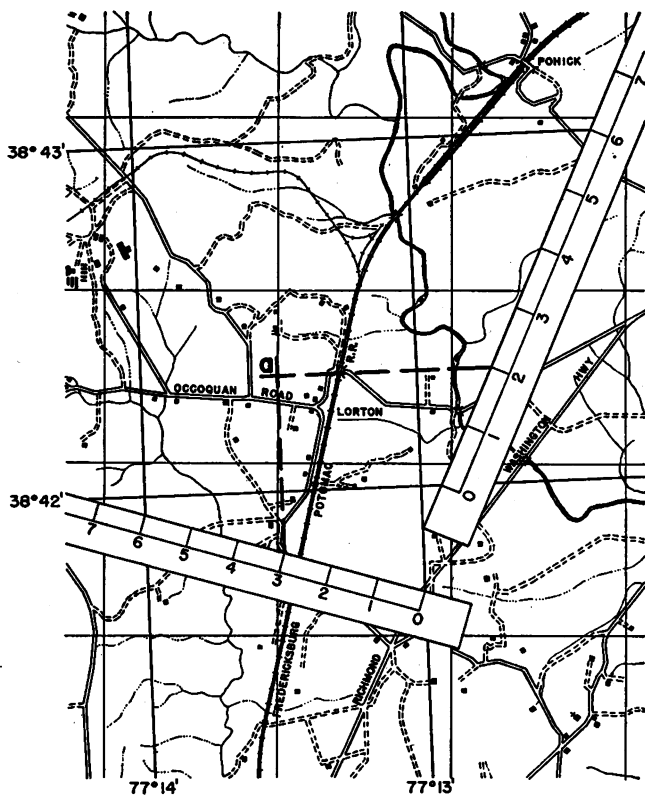


FIGURE 20.—Geographic coordinates, latitude $38^{\circ}42'20''$ N., longitude $77^{\circ}13'30''$ W.

across the significant parallels of latitude at any angle that will cause 6 convenient graduations to span diagonally the distance between them. In this position, each graduation on the scale between the 1-minute lines falls on an imaginary 10-second

line. If these graduations are further subdivided to 10 parts, as on the engineer scale, these final subdivisions would fall on 1-second lines. Point off the subdivisions required for both seconds of latitude and seconds of longitude. Through these points draw construction lines parallel to the parallels of latitude and to the meridians of longitude, respectively, to intersect at the point sought *a*.

21. Grid coordinates.—*a. Spacing of lines of the military grid.*—The military grid is formed by lines spaced 1,000 yards apart on maps of 1:20,000 scale and 5,000 yards apart on maps of 1:62,500 scale. The grid zone is described in paragraph 7.

b. Units.—The units of distance of the coordinates of the military grid are expressed in thousand yards, the distance east of the base position called the X coordinate being written first and, with a dash between, being followed by the distance north of the base position called the Y coordinate, the whole being enclosed within parentheses. *Example:* (1,359,592-1,787,383). Expressed in words the position of the point is one million three hundred fifty-nine thousand five hundred ninety-two yards grid east of and one million seven hundred eighty-seven thousand three hundred eighty-three yards grid north of the base position of the particular grid zone in which the point is situated.

c. Least reading.—The least reading is indicated by the number of decimal places and may be to yards, tens of yards, hundreds of yards, or thousands of yards.

d. Points common to a single map sheet.—All digits before the decimal which are common to the map sheet or area concerned are omitted.

e. Designation of positions.—Figure 21 illustrates the designation of the position of a point *P* the grid coordinates of which are (891.5-1,507.5). By inspection it is readily determined that the point falls somewhere between the X-grid lines 1,507 and 1,508, and somewhere between the Y-grid lines 891 and 892. This establishes the point definitely within the 1,000-yard grid square the southwest corner grid coordinates of which are (891-1,507). The engineer scale or any other suitably graduated scale may be used conveniently as a scale of proportional parts to plot the point within this grid square. To do this, place the scale diagonally anywhere across the significant

Y lines at any angle that will cause 10 convenient graduations to span diagonally the distance between the lines. In this position, each graduation on the scale between the lines falls on a 100-yard Y-grid line (imaginary). If these graduations are further subdivided to 10 parts, as on the engineer scale, these final subdivisions would fall on 10-yard Y lines, and so on. Point off the subdivision required. In figure 21 for the case in hand this happens to be a point opposite the scale division 5 in each position of the scale. Through these points draw the construction lines ca and db parallel to the Y lines and X lines, respectively, to intersect at the point sought P .

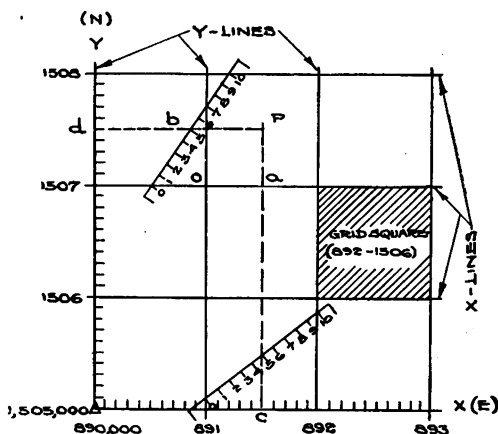


FIGURE 21.—Grid coordinates (891.5-1,507.5).

f. Determination of the distance between two points whose grid coordinates are given.—Plot the positions of the two points on the map. If no map is available, plot the relative position of the points on an improvised grid to scale. In either case scale directly the distance between the plotted points.

g. Determination of the grid or Y azimuth of a line between two points whose grid coordinates are known (fig. 22).—Plot the position of the two points on the map or plot the relative position of the points on an improvised grid to scale. Join the plotted positions by a straight line and prolong if necessary

to intersect a Y-grid line. With a protractor, measure the angle from the Y grid clockwise to the straight line indicating the significant direction. Bear in mind that a line has two directions differing in azimuth by 180°.

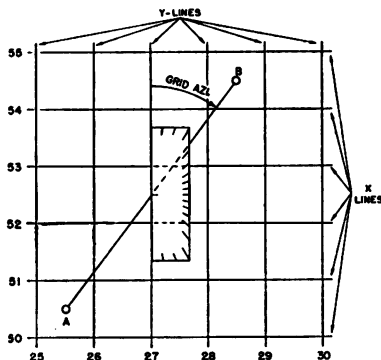


FIGURE 22.—Determination of the grid azimuth of the line AB.

SECTION III

DISTANCE

22. Definition of scale.—The word “scale” means the ratio which the distance between any two points measured on a map bears to the horizontal distance between the same two points on the ground, i. e.,

$$\text{scale} = \frac{\text{distance on map}}{\text{distance on ground}}$$

23. Methods of stating a scale.—*a. Words and figures*, as 3 inches=1 mile, mean that 3 inches on the map equal 1 mile on the ground; 1 inch=200 feet means that 1 inch on the map equals 200 feet on the ground.

b. Graphic scale is a symbol drawn on the map, divided into equal parts, each division being marked, not with its actual length, but with the distance which it represents on the ground. Graphic scales are constructed in the two parts conveniently illustrated in figure 23. That part of the scale shown to the right of the zero is referred to as the “primary scale,” or just

the "scale." It is graduated in the largest subdivisions of the unit convenient for use on the map to which it pertains. That part of the graphic scale shown to the left of the zero is referred to as the "extension." It consists of one primary division of the graphic scale subdivided into tenths, or other appropriate fractional parts representing the "least reading" of the graphic scale. The scale in figure 23 has been designed to read distance up to 300 units in hundreds of units and tens of units. If accuracy greater than to the nearest 10 units is desired, fractional parts of the significant subdivision of the extension must be estimated. Thus, in using the scale along a line to measure the distance from *A* to *B* the point on the primary scale representing the number of whole divisions of the primary scale is placed opposite *B*. The fractional part of a primary division is read on the extension opposite *A* to the

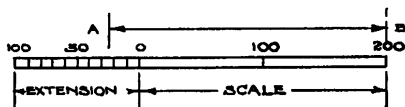


FIGURE 23.—Reading of a graphic scale.

nearest tenth. In this case the reading on the extension is two-tenths. But the point *A* is actually opposite the third space of the extension. The exact point on the scale opposite *A*—i. e., the distance which the line extends into the third space of the extension—may be estimated as four-tenths of the subdivision, or four units. Therefore, the distance *BA* may be recorded to the nearest 100 units as 200; to the nearest 10 units as 220; and finally to the nearest unit as 224.

c. Representative fraction (R. F.) of a map is one the numerator of which is unity and the denominator of which is the number of the units of distance on the ground represented by one unit on the map. The R. F. shown thus: Scale $\frac{1}{62,500}$ means 1 unit of distance on the map is equal to 62,500 such units of distance on the ground.

24. Map and ground distance equivalents.—The following table expresses, for the scales of maps indicated, the commonly used ratios of map and ground distances:

Table of map scales according to English and metric units of measure

R. F.	Miles per inch	Km. per inch	Yards per inch	Feet per inch	Inches per mile	Inches per km.	Inches per 1,000 yards	Inches per 1,000 feet	Mm. per mile	Mm. per km.	Mm. per 100 yards	Mm. per 100 feet
1. 1/16,000,000.....	252.52	406.4	444.444	1,333.333	0.00395	0.00246	0.00225	0.0075	0.1005	0.0625	0.005715	0.001905
2. 1/11,000,000.....	173.61	279.4	305.556	916.667	0.00576	0.00358	0.00327	0.0109	0.1463	0.09999	0.0083127	0.0027709
3. 1/7,000,000.....	110.48	177.8	194.444	583.333	0.0090	0.005624	0.00514	0.01714	0.2299	0.14285	0.013062	0.004354
4. 1/2,500,000.....	39.457	63.5	69.444	208.333	0.0253	0.015748	0.0144	0.0048	0.6437	.4	0.036576	0.012192
5. 1/1,000,000.....	15.783	25.4	27.778	83.333	0.0633	0.03937	0.036	0.012	1.6063	1	0.09144	0.03048
6. 1/500,000.....	7.891	12.7	13.889	41.666	0.1267	0.07874	0.072	0.024	3.2186	2	0.18288	0.06096
7. 1/250,000.....	.986	1.587	1.736	5.208	1.0137	.6289	.576	.192	25.7495	16	1.4631	.4877
8. 1/20,000.....	.3156	.508	.556	1.666	3.168	1.9685	1.8	.6	80.467	50	4.572	1.524
9. 1/10,000.....	.15782	.254	.278	1.833	6.336	3.937	3.6	1.2	160.9347	100	9.144	3.048
10. 1/5,000.....	.07891	.127	.139	417.12	12.672	7.874	7.2	2.4	321.9794	200	18.288	6.096

25. Determination of the scale of a map.—a. *By measurement of the distance between two points on the ground.*

$$\text{R. F.} = \frac{1}{\left(\frac{\text{distance on ground}}{\text{distance on map}}\right)^*}$$

*Both distances must be expressed in the same unit of measurement.

Example:

Map distance between two points=3 inches

Ground distance between the corresponding points=
5,208.3 yards

$$\text{R. F.} = \frac{1}{\left(\frac{5,208.3 \times 36 \text{ inches}}{3 \text{ inches}}\right)} = \frac{1}{62,500}$$

b. *By measurement between two points on a map of known scale.*

$$\frac{\text{R. F. of the map}}{\text{R. F. of the map of known scale}} = \frac{\text{distance on the map}}{\text{distance of the map of known scale}}$$

Example:

Distance between two points on the map of unknown scale=8 inches

Distance between corresponding points on a map of 1:20,000 scale=4 inches

$$\frac{\text{R. F.}}{1} = \frac{8}{20,000}$$

$$\text{R. F.} = \frac{1}{20,000 \times \left(\frac{4}{8}\right)} = \frac{1}{10,000}$$

26. Construction of a graphic scale.—Compute the length of one 100-yard graduation (or any other suitable division) of the primary scale and apply that length as many times as necessary along a line as indicated in figure 24. The left interval may then be subdivided if desired to serve as an extension.

Example (fig. 24): A graphic scale reading to 600 yards with a least reading of 20 yards is to be constructed for a map of

1:2,769 scale. The length of one 100-yard graduation is $\frac{100 \times 36}{2,769} = 1.3$ inches. Point off this distance six times, subdividing the left interval into five parts as the extension.

27. Time-distance scales.—In solving tactical problems or in planning military operations on maps, time-distance scales frequently prove time-saving devices of great usefulness. A time-distance scale is a scale the graduations of which are time intervals of distance to the scale of the map at a given rate of movements (figs. 25 and 26). Suppose that a time-distance scale graduated in hours and minutes of time at the marching rate of infantry, $2\frac{1}{2}$ miles per hour, is desired for use on the

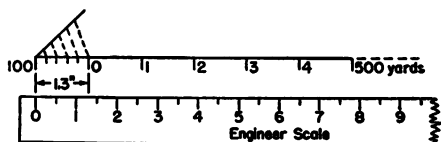


FIGURE 24.—Construction of a graphic scale.

tactical map 1:62,500. To construct such a scale the procedure is as follows:

a. (1) In 1 hour infantry marches $2\frac{1}{2}$ miles, or $2\frac{1}{2} \times 63,360 = 158,400$ inches.

(2) $158,400$ inches on the ground $= \frac{158,400}{62,500} = 2.53$ inches on a map of 1:62,500 scale.

(3) On a suitable strip of paper along a straight line ab (fig. 25) lay off as many 1-hour intervals of 2.53 inches each

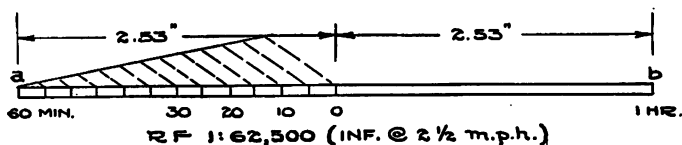


FIGURE 25.—Infantry time-distance scale.

as may be desired in the scale. Subdivide the left interval on the scale extension into minute, 5-minute (used in fig. 25), or 10-minute graduations, depending on the least reading de-

sired, mark the graduations appropriately, indicate the R. F. of the map to which the scale applies, and the marching rate to which constructed.

b. Figure 26 shows a time-distance scale reading in minutes up to 1 hour of time constructed for cavalry moving at the rate of 5 miles per hour, for use on the tactical map, 1:62,500. The length in inches of the scale is determined as follows:

(1) In 1 hour cavalry marches 5 miles, or $5 \times 63,360 = 316,800$ inches.

(2) $316,800 \text{ inches on the ground} = \frac{316,800}{62,500} = 5.07 \text{ inches.}$ The construction of the scale is similar to that described above and is illustrated in figure 26.

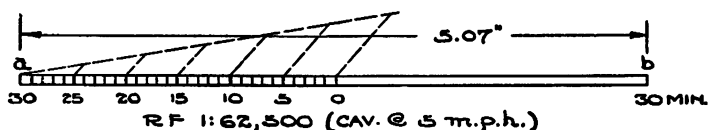


FIGURE 26.—Cavalry time-distance scale.

28. Determination of distance on the map.—*a. By means of graphic scale.*—(1) Lay a straightedge of paper or other material so that it passes through the two points and mark on it where the two points come.

(2) Note that the zero on the graphic scale is not at the end, and that the unit to the left of the zero is subdivided into smaller divisions than those to the right for use in reading small distances.

(3) Lay the unmarked edge of the paper on the graphic scale of the map with the left point at the left end of the scale; slide the paper to the right until the right end mark on the paper coincides with a division mark on the scale. To the figure above this mark, add the fraction or decimal to the left of zero on the scale. This is the required distance.

(4) If the distance is greater than the length of the graphic scale, apply the graphic scale one or more times until the remainder can be measured as previously directed.

b. By means of map measurer.—(1) Turn the small roller at the side of the dial case opposite the handle to set indicator of map measurer at zero.

(2) Set the roller at one of the given points and, holding the handle vertical, roll along the line to be measured to the second point.

(3) Under the pointer read the distance on the divisions on the dial corresponding to the representative fraction of the map.

(4) When there is no scale corresponding to the R. F. of the map, read the one marked 1:10,000 and multiply by the denominator of the R. F., taking care to place the decimal four places to the left.

(5) Some dials are divided to read the map distance in inches or centimeters. In this case map distance must be converted to ground distance by dividing by the R. F. of the map.

SECTION IV

DIRECTION

29. Units of angular measurement.—*a. Degrees, minutes, and seconds:*

A circle=360 degrees.

1 degree=60 minutes.

1 minute=60 seconds.

b. Mils.—A mil is the angle subtended by an arc of 1 unit on a radius of 1,000 units or, in other words, an angle the tangent of which is approximately (small angles) $1/1,000$. The arbitrary value of the mil adopted by the United States Army is $1/6,400$ of a circle.

c. Conversion factors:

1 degree = 17.8 mils approximately.

1 mil = 0.056 degree approximately.

= 3 minutes 22.2 seconds.

$\therefore$ degrees = $0.056 \times$ mils.

Mils = $17.8 \times$ degrees.

30. Base directions.—The characteristics of the three base directions are given in the following table:

Characteristics of base directions

Designation	Base	Departure from true north	Variation	When used
True north.....	True meridian.....	No departure.....	No variation.....	In conjunction with geographic map and for permanent records. Note.—All directions are assumed based on true north unless otherwise stated.
Magnetic north.....	Magnetic meridian.....	Termed magnetic declination and varies in the United States from 25° east in Washington State to 22° west in Maine.	Annual change has been as much as 6 minutes in some localities.	In conjunction with the magnetic compass in the field.
Grid north.....	True center meridian of the zone of the grid.	Termed gisement and increases to a maximum of approximately 3° at the edge of the grid zone.	No variation.....	In conjunction with maps on which the military grid is printed.

31. Expression of direction of angular measurements.—The characteristics of the methods used to express the direction of angular measurements are given in the following table:

Characteristics of methods of expressing directions of angular measurements

Designation	Units of angular measurement used	Base direction	Direction of measurement
Azimuths.....	Degrees or mils..	True, magnetic, or grid north, unless otherwise stated (south may be used).	Clockwise.
Bearings.....	Degrees.....	True or magnetic north and south; whichever used is designated.	Direction which gives smallest arc (must not exceed 90°) is used and is designated.

For military purpose, directions should normally be expressed as azimuths measured from true, magnetic, or grid north.

32. Relationship between true, magnetic, and grid azimuths and bearings.—This relationship is shown in figure 27.

Example:

Line BA:

Azimuth.....	60°.
Magnetic azimuth.....	66°40'.
Grid azimuth.....	57°35'.
Bearing.....	N. 60° E.
Magnetic bearing.....	N. 66°40' E.
Back azimuth.....	240°.

Line AB:

Azimuth.....	240°.
Magnetic azimuth.....	246°40'.
Grid azimuth.....	237°35'.
Bearing.....	S. 60° W.
Magnetic bearing.....	S. 66°40' W.
Back azimuth.....	60°.

33. Prismatic compass.—*a. Description.*—The prismatic compass is an instrument consisting of (figs. 28 and 29) a pivoted dial needle *b*, inclosed in a nonmagnetic metal case with a hinged cover *d*, and a prism eyepiece *a*. The pivoted dial

needle *b* has inscribed on it two azimuth circles of 360° . The inner circle is for use in reading the face of the compass. The outer circle is for use in reading azimuths through the eyepiece *a*. The least reading of the compass is 1° .

b. Measurement of an azimuth with the prismatic compass in daylight (fig. 28).—Raise the eyepiece *a* and the cover *d* vertically and lower the needle dial at *g*. Grasping the com-

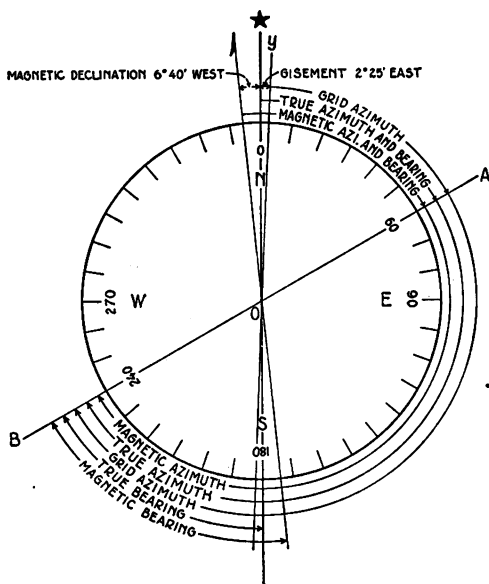


FIGURE 27.—Relationship between true, magnetic, and grid azimuths and bearings.

pass with the thumb and forefinger as shown in figure 28, hold it horizontally in front of the face, the aperture of the eyepiece immediately in front of one eye with the other eye closed. Turn about carefully until the object the azimuth of which is desired is bisected by the etched line *f* on the cover, as viewed through the slit in the eyepiece. In case the glass cover casing is broken, a horsehair or thread, to serve as a substitute for the etched line, may be passed through the holes drilled

for that purpose. Allow the needle to come to rest. Then read the azimuth sought from the outer circle as viewed through the aperture. If greater stability of the needle is desired, the compass should be supported on a solid platform or used in a prone position on the ground. The plunger *i*, shown in figure 29, may be used to dampen the needle dial in order to bring it more quickly to rest.

c. To follow a course of given azimuth with the prismatic compass in daylight.—(1) Hold the compass as described in *b* above.



FIGURE 28.—Prismatic compass showing the compass open and in position for measuring an azimuth in daylight.

(2) Turn about carefully until the azimuth of the course can be read through the aperture of the eyepiece. In that position select a house, tree, rock, or other visible feature of the landscape on the line of sight defined by the etching on the cover as viewed through the slit of the eyepiece.

(3) Close the compass and proceed by the shortest practicable route to the object sighted.

(4) Repeat as necessary, but never attempt to follow the course without previously selecting markers on the terrain on which to guide since it is very easy to drift laterally and imperceptibly on a compass course.

d. To follow a course of given azimuth at night (fig. 29).—

(1) Use the radiolite marker *c* on the movable index ring to lay off the course on the circle about the outside of the compass case. Clamp *h* controls the movable ring.

(2) Hold compass horizontally and carefully turn about until the needle points to the marker *c* on the movable ring. The course is now indicated by the radiolite markers *j* and *j'*.

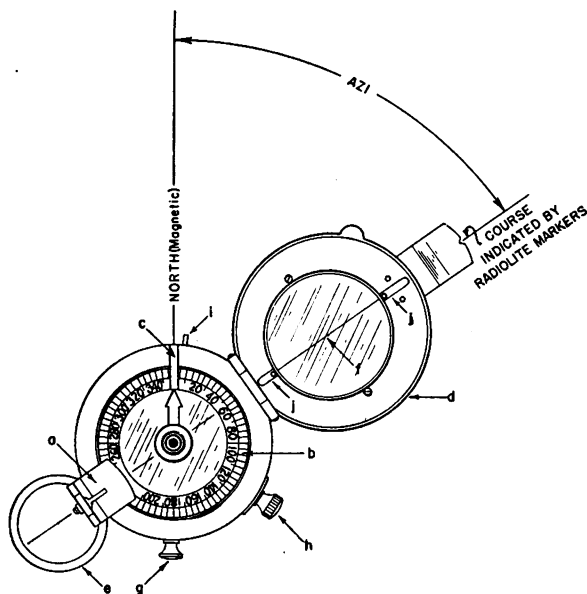


FIGURE 29.—Prismatic compass, showing the compass opened for measurement of an azimuth at night by means of the radiolite marker.

(3) On a clear night select irregularities of the sky line or heavenly bodies on which to guide.

(4) On a dark night two persons may be necessary if the mission is important, one proceeding along the course to the limit of visibility, then waiting for the other and repeating as necessary.

34. Protractor.—*a. Relationship between the semicircular and the rectangular protractor.*—This is indicated by figure 30 which shows one superimposed upon the other.

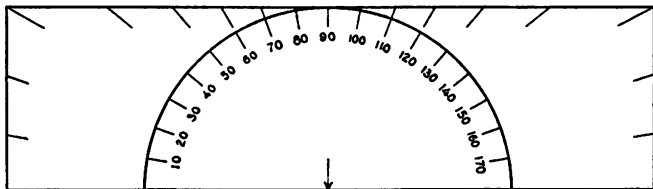


FIGURE 30.—A circular and a rectangular protractor superimposed one upon the other.

b. Use of a rectangular protractor (fig. 31).—Assuming the Y-grid lines are available on the map and the angle which magnetic north makes with grid north is shown on the map margin to be the sum of the magnetic declination $6^{\circ}21'$ and gisement $2^{\circ}35'$ or $8^{\circ}56'$, to lay off the magnetic azimuth of a line *AB* the procedure is as follows:

(1) Join the points *A* and *B* by a fine, lightly drawn line and prolong until it crosses the nearest Y-grid line and extends beyond the edges of the protractor.

(2) By inspection the azimuth is seen to be less than 180° and therefore should be measured on the outside or lesser azimuth circle (0° to 180°) of the protractor with the protractor placed on the east side of the direction line.

(3) Place the protractor along the intersected grid line 65 and shift it until the index coincides with the point where *AB* prolonged crosses the grid line. About this point as a pivot, turn off an angle of $8^{\circ}56'$ (or 9° in practice, since the difference is unmeasurable) counterclockwise. The index edge of the protractor is now on the magnetic meridian. The value of the azimuth angle sought is read $61^{\circ}00'$ at the point on the outside azimuth "circle," where the line *AB* prolonged cuts the edge of the protractor.

(4) Suppose, however, the problem were to measure the magnetic azimuth of the line *BA*, which is the back azimuth of the line *AB* and differs from it by 180° . By inspection this is seen to be greater than 180° , requiring use of the inner

"circle" of graduations (180° to 360°) with the position of the protractor on the opposite side of the grid line. The procedure is similar to that just described except the protractor is placed on the west side of the 65 grid line, the angle $8^{\circ} 56'$

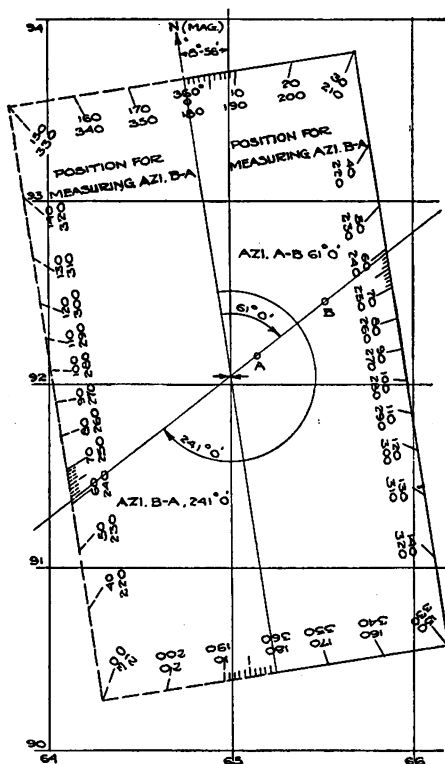


FIGURE 31.—Use of the rectangular protractor.

is turned off counterclockwise from the south end of the protractor, and the angle of $241^{\circ}0'$ is read on the inner "circle" where BA prolonged crossed the graduated edge of the protractor.

SECTION V

RELIEF

35. Methods of indicating relief.—Data pertaining to the methods of indicating relief are given in the following table:

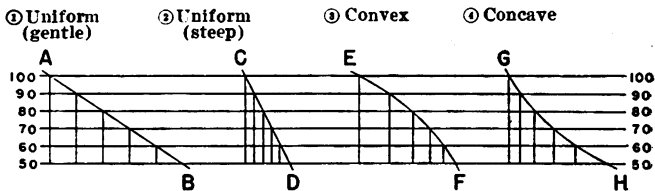
Methods of indicating relief

Method or symbol	Meaning of symbol	Representation of slope	Remarks
Contours.....	Loci of points of same elevation with reference to sea level.	Contours at right angles to steepest slope. Steepness indicated by spacing.	Distinct method in itself of showing relief.
Form lines.....	Approximate contours.	do.....	Used when it has not been possible to establish accurately the position of contours.
Hachures.....	Line of steepest slope.	Hachures are in direction of line of steepest slope. The more heavily drawn and closer together, the steeper the slope.	Distinct method in itself of showing relief but on contoured maps depressions, mine dumps, levees, and other banks which constitute important topographic features but which cannot be shown by the regular contour interval are shown by means of hachures.
Layer tint.....	Shows by color variation area of ground lying between chosen contour limits.	-----	Invariably associated with contours. Relief in general stands out more and is, in consequence, much easier to read but minor features or variations in relief are lost and the impression is conveyed that the ground is level between contours limiting the shades of tint.
Spot heights..	Give elevation to the nearest foot of important features between contours.	-----	Used on practically all maps in conjunction with the other methods listed above.

36. Representation of slope by contours (fig. 32).—The slope of the ground is indicated by the spacing of contours. Thus in figure 32 ① and ② uniform slopes shown above in profile are indicated below by contours, figure ① showing a gentle slope and ② a steep slope. The spacing of the contours increasing at the top of the hill as in figure 32 ③ indicates a convex slope

with accompanying dead areas concealed from the geographic crest. The spacing of the contours decreasing at the top of the hill as in figure 32 ④ indicates a concave slope permitting a coincidence of the military and geographic crests. The extent to which slope may be represented is limited by the contour interval. If the contour interval is large, unrepresented ground features between the contours may be concealed from the map reader.

PROFILES



PLANS

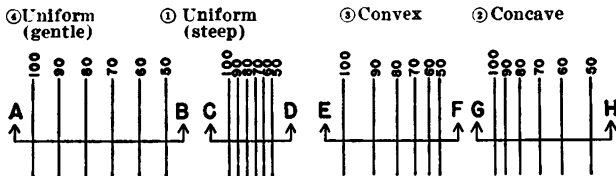


FIGURE 32.—Representation of slope by contours.

37. Determination of the elevation of a point on a contoured map.—Generally the point will lie between two heavy contour lines the elevations of which are indicated. Determine the elevations of these by inspection. From the contour interval stated in the margin of the map determine the elevations of the two contour lines on each side of the point in question. Estimate the elevation of the point by the relation of its distance from the nearest contour to the contour spacing. When the point lies within a closed contour forming a knob or a depression, only an approximation is possible.

38. Slope or grade.—*a. Determination and expression.*—The determination and expression of a slope between two points *A* and *B* on a map are illustrated in figure 33. The slope of roads, railroads, embankments, and cuts is referred to as grade.

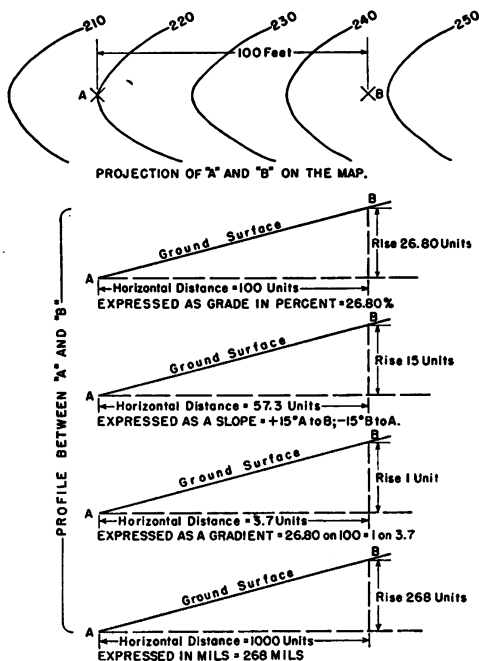


FIGURE 33.—Determination and expression of slope between two points *A* and *B* on a map.

b. Units of slope measurement.—The characteristics of these units are shown in the following table:

Units of slope

Name	Definition	How computed	Remarks
Percent...	Number of units of vertical rise in a horizontal distance of 100 units.	$\frac{\text{Difference in elevation} \times 100}{\text{Horizontal distance}}$	Most convenient and common method used to express slope.
Degrees...	Angular arc subtended.	$\frac{\text{Difference in elevation} \times 57.3^1}{\text{Horizontal distance}}$	Unit of measurement of field instruments.
Gradient	Ratio of elevation difference to distance expressed as a fraction (i. e., tangent of angle of slope).	$\frac{\text{Difference in elevation}}{\text{Horizontal distance}}$	Unit of measurement of steep slopes, viz, road cuts, embankments, trenches, etc.
Mils.....	Angle which subtends an arc of 1 unit at a radius of 1,000 units	$\frac{\text{Difference in elevation} \times 1,000}{\text{Horizontal distance}}$	On slopes greater than 350 mils the arbitrary mil of $\frac{1}{6,400}$ of a circle begins to show appreciable errors.

¹ For small angles only.

c. Conversion factors:

1 degree = 1.75 percent.¹

1 degree = 17.5 mils.¹

1 percent = 0.57 degree.¹

1 percent = 10 mils.

1 mil = 0.1 percent.

1 mil = 0.057 degree.¹

¹ Approximate only and limited to slopes of less than 5 degrees.

39. Intervisibility.—On account of the inaccuracies of maps, it is impossible to determine exactly how much ground is visible from any given point over an obstructing area. If a correct interpretation of the map shows a given point to be just barely visible, it would be unsafe to say that the point could be seen. The fastest method of determining intervisibility is by inspection. Most problems of intervisibility encountered in the field can be solved by this method. When inspection of

the map leaves a doubt as to intervisibility or where greater accuracy is desired, the following methods are available:

Method	Advantages	Disadvantages
Profile method.....	Because of clarity and completeness affords the best results, especially in determining visible areas.	Most laborious method and drafting material necessary.
Graphical method.....	Faster than profile method..	Drafting material necessary.
Rubber band method.	Applies more quickly the same principles as the preceding method.	The rubber band must be thumbtacked to a map board in order to allow leisurely study.

40. Visibility rules.—The following rules may be helpfully applied in determining the intervisibility by inspection of two points shown on a map.

a. The points if on opposite sides of a valley and located well above the intervening ground are intervisible.

b. If between the two points there is a feature represented higher than both, they are not intervisible.

c. If between the two points a feature is represented which is higher than one of the points, the points may or may not be intervisible.

d. If the slope of the ground between the two points is convex, they will not be intervisible.

e. If the slope of the ground between the two points is concave, they will probably be intervisible.

f. When the ground between the two points is level, their intervisibility will depend upon the presence of vegetation and works of man.

41. Methods of determining intervisibility other than by inspection.—*a. Profile method.*—Figure 34 ① illustrates the profile method of determining whether a target at *B* (elevation 1,100) is visible from an observation post at *A* (elevation 1,130), and, if not, the height of mask at *C* and the defilade at *B*. The visible areas along the profile are also indicated.

b. Hasty profile method (fig. 34 ②).—In this method one must first determine by inspection critical points which affect visibility. In doing this the visibility rules given in paragraph 40 apply. The effect of the selected critical points upon

visibility is accurately determined by plotting them to elevation and scale as shown in figure 34 ②.

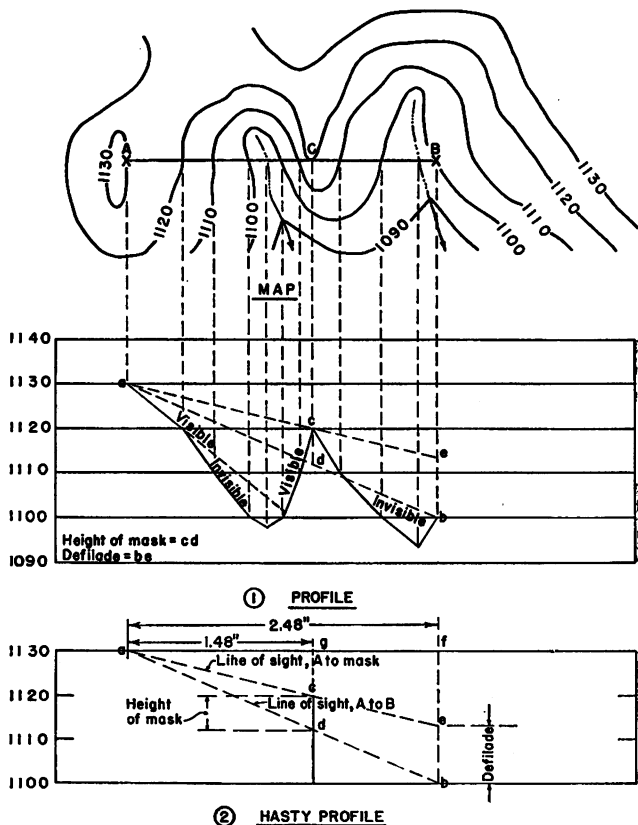


FIGURE 34.—Determination of visibility by profile (including hasty profile).

c. Graphical method.—(1) Lay off on a sheet of paper, parallel to its edge and at a convenient distance, a scale of equal parts. Number these parts in correspondence with the range

of elevations to be investigated in the reverse order so that diagonals connecting points to be investigated for intervisibility and corresponding elevations on the scale intersect conveniently. Place the edge of the sheet of paper along the line of sight.

(2) (Fig. 35.) If it is desired to determine the height of the line of sight between points *A* and *B* with respect to intermediate points, join points *A* and *B* by diagonals *Aa* and *Bb* with corresponding elevations on the scale. Mark the point

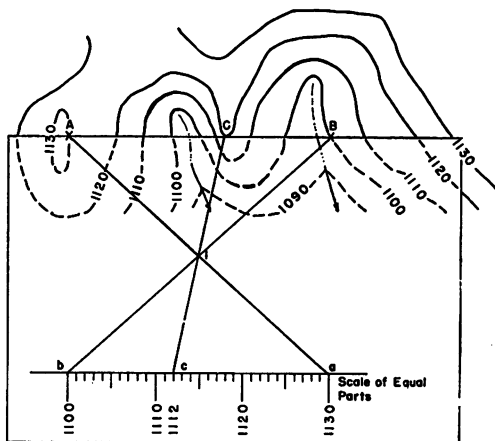


FIGURE 35.—Visibility by graphical method, determination of height of mask.

of intersection *I*. To determine if *C* masks *B* from *A* draw from *C* through *I* the line *CI* which when prolonged intersects the scale at *c*. The scale reading at *c*, 1,112, gives the elevation of the line of sight at *C*. Consequently, *B* is not visible.

(3) (Fig. 36.) If it is desired to determine the obstruction to visibility from point *A* caused by the ridge at point *C*, join *A* and *C* by diagonals *Aa* and *Cc* with corresponding elevations on the scale. Mark the point of intersection *I*. Then by trial swing a straightedge upon the intersection *I* and deter-

mine on what portion of the line AC beyond point C the height of the ground is lower than the corresponding scale value. The ground along this portion of the line AC is invisible from A and the difference between the ground elevation and the scale value determines the height of the defilade at any point.

d. Rubber band method (fig. 37).—(1) A rubber band may be adapted to the graphical methods just described. Take a narrow rubber band, distend it and divide it into a scale of equal parts corresponding to the difference in elevation between the two points the intervisibility of which is under

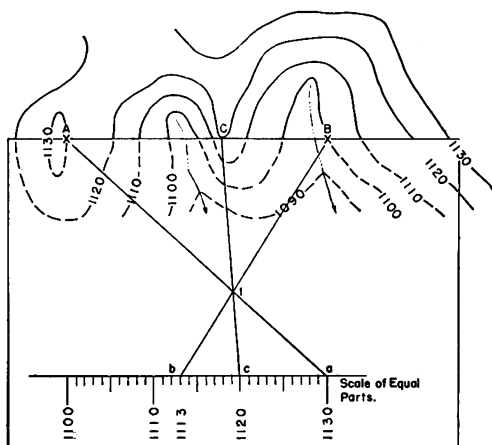


FIGURE 36.—Visibility by graphical method, determination of defilade.

investigation. In order to determine the elevation at the mask C of the line of sight between A and B , stretch the rubber band across the map with the zero of the scale at the point of low elevation B , and the 30 mark at A which is 30 feet higher than B . The elevation of the line of sight at any point may easily be determined from the rubber band and compared with the elevation of the ground at the same point. If the ground is lower there is no mask. If the ground is higher it constitutes a mask. The height of the line of sight at C above the elevation of B is read from the rubber band as

12 feet. Since *C* is 20 feet higher than *B*, the line of sight fails to clear the mask by 8 feet.

(2) To determine the height at *B* of the line of sight from *A* to the mask *C*, hold the 30 mark on *A* but stretch the rubber band until the mark corresponding to the elevation of *C* (20) is at *C*. The elevation of the line of sight above *B* may then be read from the mark on the rubber band appearing at *B*.

(3) Each end of the rubber band may be wrapped about a piece of thin cardboard and pierced by a thumbtack. This will enable the map reader to tack the rubber band in the position

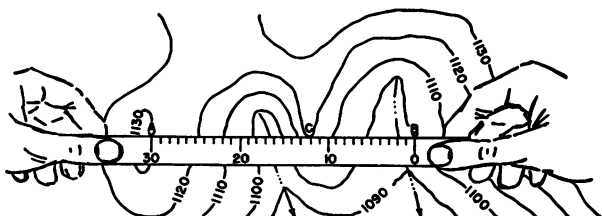


FIGURE 37.—Visibility by rubber band method.

desired on the map for a leisurely study of the situation under investigation. The map must be flat on a map board, preferably of beaverboard.

42. Visibility diagrams.—Visibility diagrams indicate which portions of the ground are visible and which are invisible to an observer at some definite observation post. They are also a practical aid to identifying objects from an observation post when a good map is available. To construct a visibility diagram, identify the observation post and the reference object on the map, draw a line joining these two, and make it 0°. Set off lines at 10° interval, radiating from the zero line on either side of it. Study the features, mark on the map the objects and features which interfere with the view, and then draw in those areas which are invisible from the observer's position.

SECTION VI

TYPES AND CHARACTERISTICS OF AERIAL PHOTOGRAPHS AND MOSAICS

43. **Types of aerial photographs.**—Aerial photographs may be grouped into three types, plain verticals, composite verticals, and obliques. Plain verticals are made with single lens cameras held so that the optical axis is as nearly as possible vertical. Composite verticals are made with multiple lens cameras, the pictures of which have been transformed photographically, joined, and mounted in a composite, forming in effect a single plain vertical of great scope. The multiple lens cameras used by the Air Corps have one central lens with a

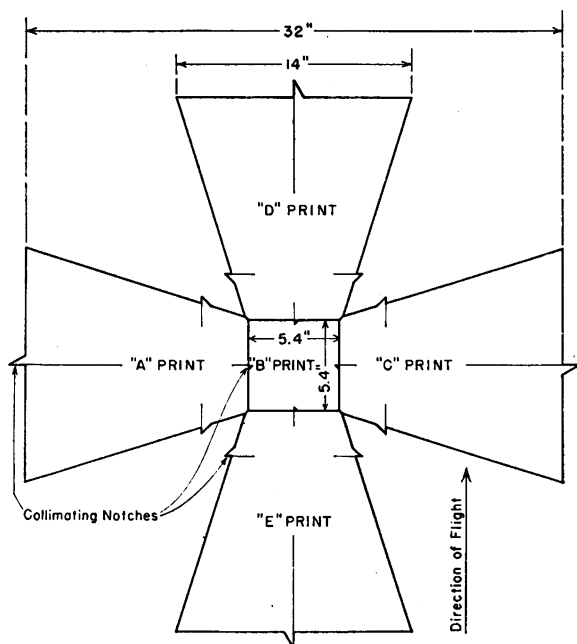


FIGURE 38.—Vertical composite photograph made by the type T-3A five-lens aerial camera.

vertical optical axis and from two to four peripheral lenses which are tilted. The resulting composite (fig. 38) is irregular in shape. Obliques are made with a single lens camera with the optical axis inclined usually about 30° with the horizontal. Plain vertical photographs when reproduced lithographically with marginal data consisting of the scale, a base direction, the military grid coordinates of the center point, and a local inch grid are called photo-maps. A mosaic is a composite photograph formed by joining two or more plain verticals or composite verticals.

44. Characteristics.—Characteristics of the various types of photographs are listed in the following table:

Characteristics of photographs

Camera	Focal length in inches	Photo size in inches	Width covered by single photo in miles at scales			Flying altitudes in feet for scales of—			Flight line spacing in miles to give an overlap equivalent to 50 percent overlap on 7-by 9-inch photo		
			1:10,000	1:20,000	1:40,000	1:10,000	1:20,000	1:40,000	1:10,000	1:20,000	1:40,000
K-3B-----	8.25	7 by 9-----	1.42	2.84	5.68	6.875	13,750	27,500	0.71	1.42	2.84
K-3B-----	12	7 by 9-----	1.42	2.84	5.68	10,000	20,000	40,000	.71	1.42	2.84
K-7C-----	24	9 by 18-----	2.84	5.68	11.36	20,000	40,000	80,000	1.42	2.84	5.68
Zels:											
4-lens-----	5.32	9.5 by 9.5 (usable)-----	1.50	3.00	6.00	4,440	8,870	17,730	.79	1.58	3.16
9-lens-----	1.97	9.8 by 9.8-----	1.55	3.10	6.19	1,640	3,280	6,570	.84	1.67	3.33
T-2A (4-lens)-----	6.5	Center, 5 by 5; composite, 12 by 19, approximately.	3.18	6.37	12.74	5,420	10,840	21,680	2.48	4.96	9.93
T-3A (5-lens)-----	5.9	Center, 5.4 by 5.4; composite, 32 by 32, approximately.	5.1	10.2	20.4	4,920	9,840	19,680	4.05	8.11	16.22

¹ Impractical flying altitudes due to airplane limits or bumpy air.

45. Scale.—*a. By comparison with a map (fig. 39).*—The average scale of a photograph may be computed by the comparison of distances between pairs of points on the photograph with corresponding distances between the same points on the ground or on a map. Because of displacements due to tilt and relief the points chosen should be so located on the photograph that the straight lines joining them pass through or near to the center of the photograph and well across the face. It is desirable to select more than one such pair of points. The denominator of the R. F. sought is the average

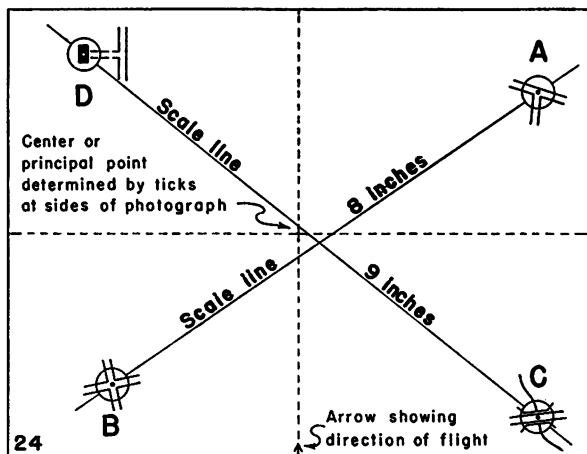


FIGURE 39.—Plain vertical aerial photograph showing location of scale lines for the determination of average scale.

of the denominators of the R. F.'s given by the several scale lines selected.

$$\begin{aligned} \text{R. F. of any scale line} &= \frac{\text{photo distance in inches}}{\text{ground distance in inches}} \\ &= \frac{\text{photo distance}}{\text{map distance}} \times \text{R. F. of map} \end{aligned}$$

Average R. F. of photo=

$$\frac{1}{\text{mean of the denominators of the R. F.'s of the scale lines}}$$

Example:

Distance AB on photo=8 inches.

Distance AB on map, 1:20,000=6 inches.

Distance CD on photo=9 inches.

Distance CD on map, 1:20,000=6.65 inches.

Using scale line AB :

$$\text{R. F.} = \frac{8}{6 \times 20,000} = \frac{1}{15,000}$$

Using scale line CD :

$$\text{R. F.} = \frac{9}{6.65 \times 20,000} = \frac{1}{14,778}$$

$$\text{Average R. F. of photo} = \frac{1}{14,889}$$

b. By lens height (fig. 40).—The scale may also be computed from the lens height.

$$\text{Scale} = \frac{\text{focal length of the camera } (f) \text{ in feet}}{\text{height of the lens above the ground } (H) \text{ in feet}}$$

Example:

Focal length of the camera is 6 inches or $\frac{6}{12}$ foot.

Altitude of the airplane is 10,000 feet above sea level.

Elevation of the ground is 1,000 feet above sea level.

Lens height=10,000 feet—1,000 feet=9,000 feet.

$$\text{Scale} = \frac{6 \div 12}{9,000} = \frac{1}{18,000}$$

46. Scope.—The area of an aerial photograph may be determined from the scale of the photograph or from the camera height.

$$\begin{aligned} \text{Scope} &= \frac{\text{width}}{\text{R. F.}} \times \frac{\text{length}}{\text{R. F.}} \\ &= \frac{\text{width} \times H}{f} = \frac{\text{length} \times H}{f} \end{aligned}$$

Example:

1. Dimensions of photograph are 7 by 9 inches.

Scale of photograph is 1:12,000.

$$\begin{aligned} \text{Scope} &= (7 \times 12,000) \times (9 \times 12,000) \text{ square inches} \\ &= 2.26 \text{ square miles.} \end{aligned}$$

2. Dimensions of photographs are 7 by 9 inches.

Focal length of camera lens is 6 inches = $\frac{6}{12}$ foot.

Elevation of airplane = 6,000 feet.

$$\text{Scope} = 7 \text{ inches} \times \frac{6,000}{\frac{6}{12}} \times 9 \text{ inches} \times \frac{6,000}{\frac{6}{12}}$$

square inches

= 2.26 square miles.

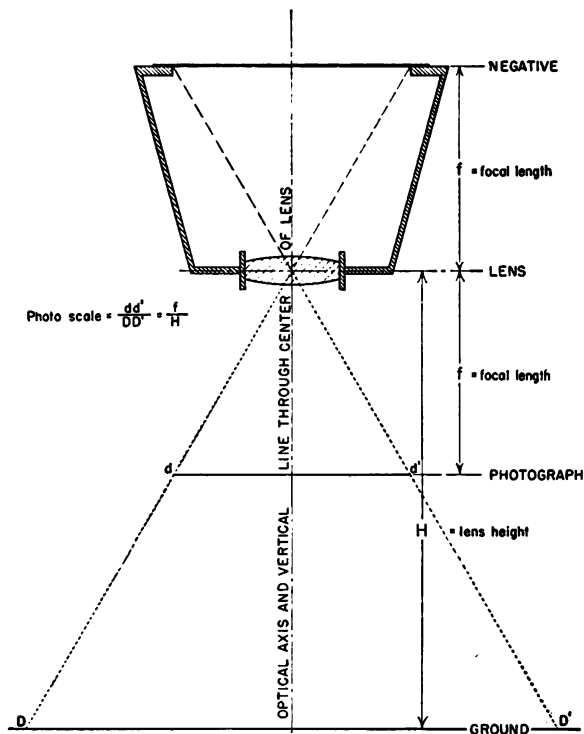


FIGURE 40.—Relationship of scale of a photograph to lens height.

47. Indexing and plotting.—*a. Pertinent data borne on photographs.*—Vertical photographs have indicated upon them their index number, principal (center) point or collimating marks by which the point can be determined and, in the case of the "T" type, an image of the level dials. Other pertinent data, such as the date and hour of flight, altitude, type and focal length of camera, are usually furnished on an index map or in some other form accompanying the photographs.

b. Index map (fig. 41).—An index map shows comprehensively the relation of photographs to one another and to the area photographed.

c. Template.—Photographs can best be plotted on a map by means of a template constructed of transparent material which represents the dimensions of the photograph to the scale of the map.

$$\text{Length of side of template} = \frac{\text{side of photo} \times \text{R. F. of map}}{\text{R. F. of photo}}$$

Example: To determine dimensions of a 7- by 9-inch photograph, scale 1:12,000 on a map, scale 1:20,000—

$$\text{Long side} = \frac{9 \times 12,000}{20,000} = 5.4 \text{ inches.}$$

$$\text{Short side} = \frac{7 \times 12,000}{20,000} = 4.2 \text{ inches.}$$

$$\text{Template of photograph} = 5.4 \text{ by } 4.2 \text{ inches.}$$

d. Location.—The location of a photograph on a map having the military grid is fixed by the grid coordinates of the center of the photograph.

48. Errors present in photographs and mosaics (fig. 42).—

a. Relief.—Due to relief, points on aerial photographs are displaced radially on a line drawn through the point where a vertical line from the lens pierces the ground. This point is called the plumb point. Except in the presence of excessive tilt, for practical purposes this point is assumed to be the center of the photograph which is termed the principal point. This point is usually indicated by ticks on the sides of the photograph.

b. Tilt.—Due to tilt, points on aerial photographs are displaced radially on a line drawn through a point midway between the plumb point and the principal point called the iso-

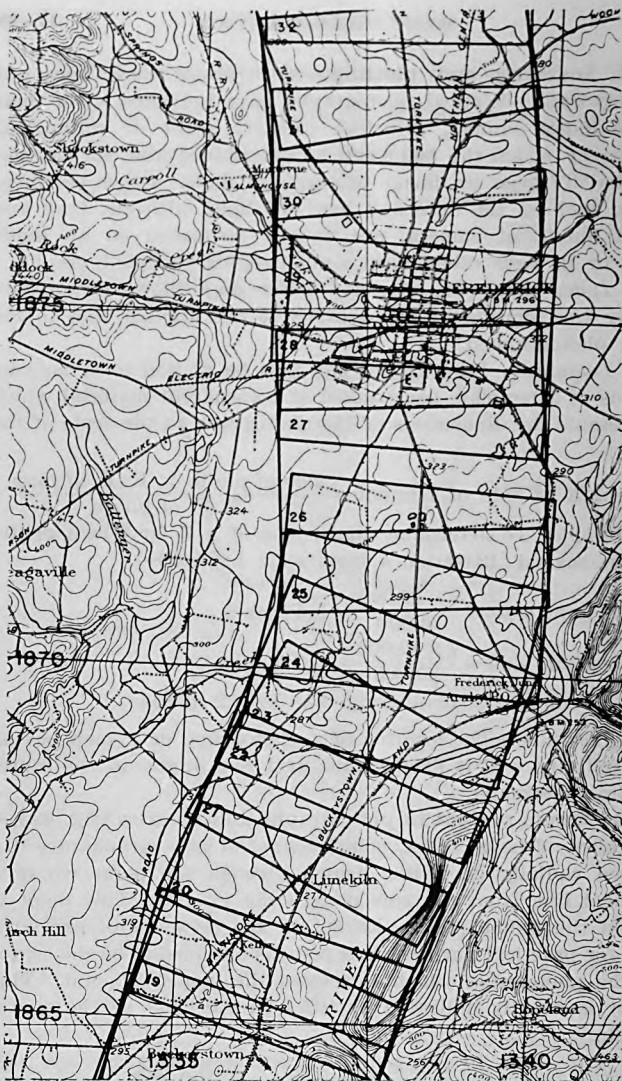


FIGURE 41.—Index map showing a strip of "K" type aerial photographs plotted on a map of 1:62,500 scale.

center. Except in the presence of excessive tilt, for practical purposes this point is assumed to be the center of the photograph.

c. Scale and azimuth errors.—Due to the displacements referred to above, errors of scale and azimuth are usually present both in photographs and in mosaics made from them even though the mosaics are fitted to points of accurately determined control.

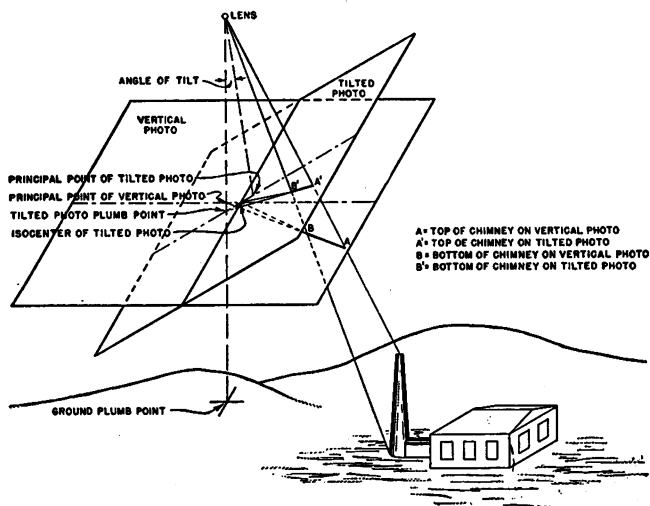


FIGURE 42.—Displacement of position on an aerial photograph due to relief and tilt.

SECTION VII

INTERPRETATION OF AERIAL PHOTOGRAPHS

49. Orientation of single photographs.—The two main aids in the identification of objects on vertical photographs are their shape and their shade or tone. The shape of an object is often more discernible by the shadow it casts than by the object itself for the reasons that its vertical dimensions may be more characteristic than its horizontal dimensions, and its

shade may blend into the surrounding landscape whereas its shadow may give a contrasting tone. A shadow will sometimes make relief discernible but if the photograph is not held in a position so that the direction of the shadows coincides with the observer's sense of direction, the shadow effect of relief is reversed, i. e., a depression will appear as an elevation. Consequently in reading vertical photographs, whether single, stereoscopic pairs, or mosaics, the lighting conditions appearing in the photographs should be reproduced. This is accomplished as follows:

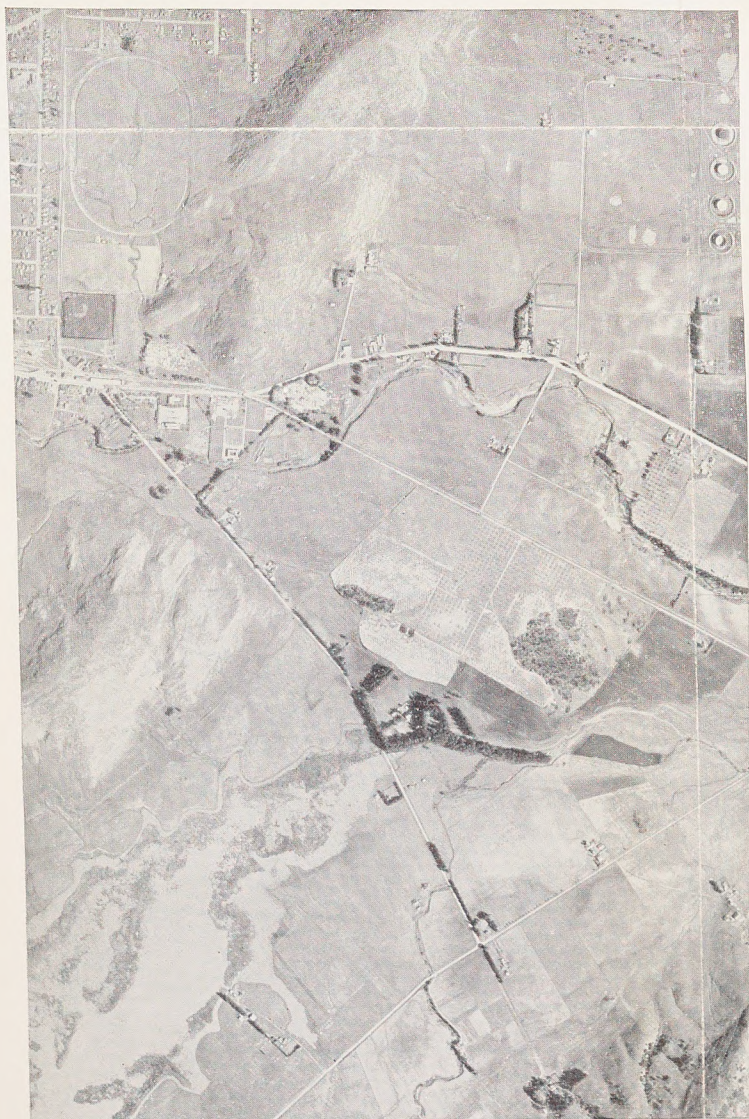
a. First study the photographs and from houses or trees determine the direction of shadow. Cuts and embankments are dangerous as they are confusing.

b. Orient the photographs so that the shadows fall toward the reader and away from the source of light.

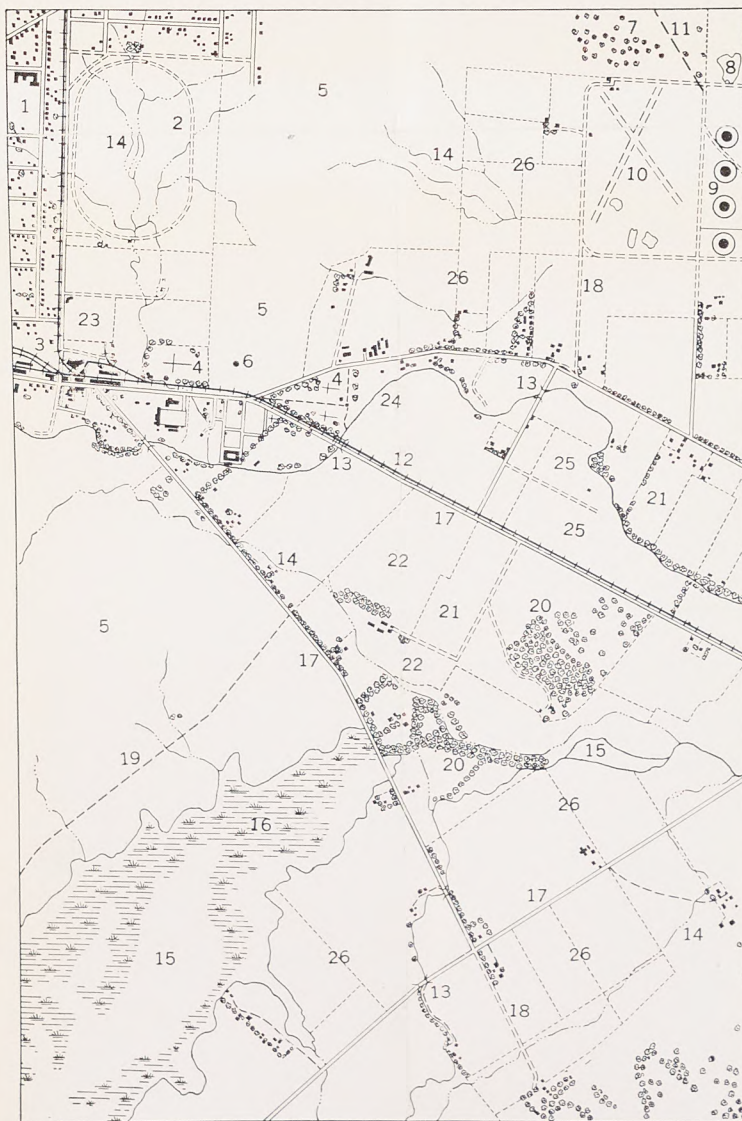
50. Interpretation of detail.—Figure 43 gives a representation of the chief topographical features appearing on plain vertical photographs of 1:20,000 scale. One of the best methods of training interpreters of aerial photographs in identifying objects is to have the students compare objects on the ground with the representation of those objects on an aerial photograph. Experience in identifying the characteristic appearance of the various objects of military importance on an aerial photograph is the best teacher. Detail can best be interpreted by the examination of a stereoscopic pair of photographs by means of a stereoscope. This permits the perception of shape and form which are lacking in the single vertical photograph.

51. Interpretation of relief.—Direct evidence of relief can be obtained only by stereoscopic observation of an overlapping pair of vertical photographs or, to a limited degree, by an oblique photograph. Single vertical photographs afford only certain clues. The most important are streams and ponds. Others are the alinement of roads and shadows arising from slopes, though these, especially the latter, may be very misleading.

52. Stereoscopic examination of aerial photographs.—a. *Photographs*.—Two overlapping photographs of the same scale taken from different camera positions are required. With a standard stereoscope best results are obtained from two con-



① Vertical aerial photo.



② Map of area shown on photo.

FIGURE 43.—Interpretation of photographic detail.

1. City.
2. Race track of fair grounds.
3. Railroad yards.
4. Cemetery.
5. Topography with low brush on hillside.
6. Concrete water tank.

7. Scattered wood.
8. Pond.
9. Oil tanks.
10. Airport with runways.
11. Oil pipe line.
12. Railroad.
13. Bridges.

14. Intermittent drainage.
15. Lake.
16. Marshes.
17. First class roads.
18. Secondary roads.
19. Trail.
20. Woods.

21. Orchards.
22. Vineyards.
23. Baseball park.
24. Streams.
25. Pasture.
26. Cultivated fields.

secutive vertical photographs of a strip taken with an overlap of approximately 60 percent, which are devoid of tilt.

b. Stereoscope.—The stereoscopic effect is obtained by viewing simultaneously a pair of overlapping photographs presenting different viewpoints in such a manner that the view of each eye is restricted to a single photograph. Any standard stereoscope serves this purpose. A mirror stereoscope has the advantage of presenting a large field of view while a lens stereoscope permits the introduction of magnification. A stereoscope may be improvised by means of two magnifying reading glasses or may even be dispensed with by one whose eyes are practiced in seeing stereoscopically.

c. Conditions under which observations should be made.—

(1) Both pictures should be equally legible. For this purpose both eyes of the observer should be of equal power or corrected by optical aids and the two photographs should be equally distinct and equally illuminated.

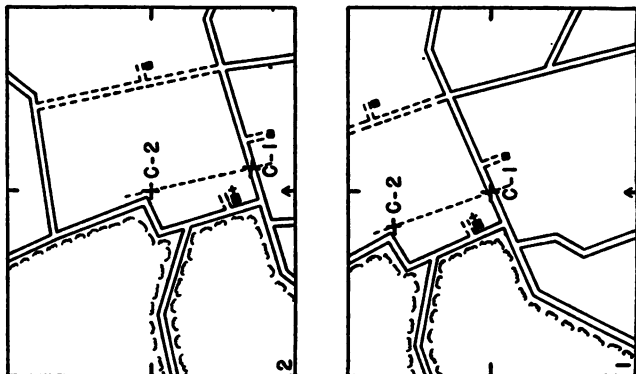
(2) The shadows on the photographs should fall away from the source of light.

(3) The pictures should be so arranged in respect to themselves and to the eyes of the observer that exposure conditions are restored. The distance between the centers of the two photographs corresponds to the base between camera positions and the positions of the eyes correspond to the camera lens positions. The eyes must be parallel not only to the line joining the centers of the photographs but also to a line on each photograph drawn between points of detail marking the corresponding two center points.

53. Procedure for stereoscopic examination.—The following procedure should be observed when making a stereoscopic examination of aerial photographs:

a. (Fig. 44.) Take a stereoscopic pair of vertical aerial photographs and by means of their collimating marks determine the principal or center point of both.

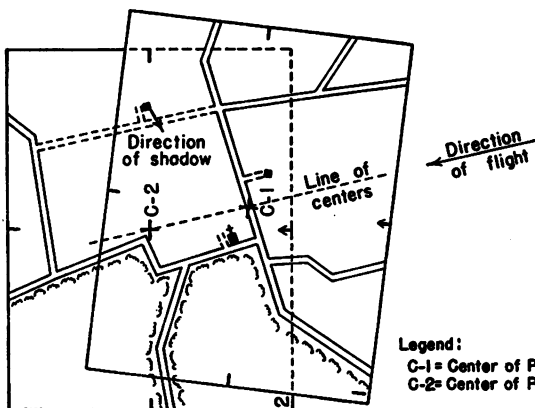
b. On each photograph mark the point corresponding to the center of the other photograph and draw a line between it and the center of the photograph. This line must be held parallel to the eye base while the photographs are viewed by means of a stereoscope.



Legend:

- C-1 = Center of Photograph #1
- C-2 = Center of Photograph #2
- = Line joining center points

FIGURE 44.—Stereoscopic examination of aerial photographs. Marking of line of centers.



Legend:

- C-1 = Center of Photograph #1
- C-2 = Center of Photograph #2

FIGURE 45.—Stereoscopic examination of aerial photographs. Orientation of the photographs.

c. (Fig. 45.) Take the two photographs and orient them in the direction of flight so that the overlapping detail common to both is roughly in coincidence. Note the direction of shadow. The shadows should fall toward the observer. If not, turn them about 180° and reorient them as before.

d. Place the photographs under the stereoscope so that the left print (taken by the camera on the left of the overlap area) is observed by the left eye and the right print by the right eye.

e. (Fig. 46.) Shift the photographs so as to bring the two lines drawn between the corresponding center points parallel to the eye base and in prolongation with one another in the center of the field of view of the stereoscope.

f. Without changing the position of the lines drawn through the corresponding center points, bring together or separate the photographs until stereoscopic conditions of fusion are best fulfilled. This may be facilitated by placing one finger over points of corresponding detail on each photograph and, by varying their separation, first fusing the fingers.

g. The relief effect may be magnified but slightly distorted by increasing the separation of the photographs.

54. Effect of faulty orientation.—Faulty orientation of a stereoscopic pair with respect to one another and with respect to the eye base introduces false parallax differences and lack of correspondence causing distortions in the stereoscopic model. Its effect upon the observer is indicated by difficulty in fusion and by eye strain.

55. Effect of tilted photographs.—Photographs which are tilted cannot be fully brought into correspondence and must be shifted as the field of view of the observer is moved from point to point. Distortion of relief results from such a condition.

56. Effect of reversal of positions of stereoscopic pair.—If the position of two photographs forming a stereoscopic pair is reversed so that the left print (taken by the camera on the left side of the overlap) is viewed by the right eye and the right print by the left eye, the impression of relief is reversed, i. e., the point of lowest elevation is reconstructed nearest to the eye and appears to be of highest elevation. Practical use

may be made of this principle in that drainage lines may be traced by making them appear as ridge lines.

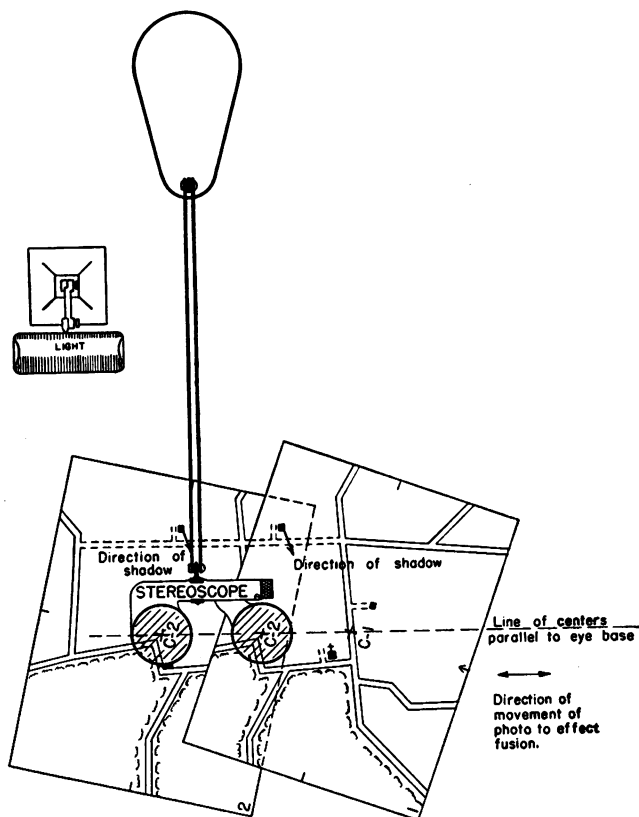


FIGURE 46.—Stereoscopic examination of aerial photographs. Photographs oriented under a stereoscope.

57. Grid for photographs and mosaics.—*a. Military grid.*—The military grid when shown on mosaics is only approximate. This grid may be transferred from a gridded map to an un-

gridded photograph or mosaic of known scale by the following procedure:

(1) Select on the photograph (fig. 47) three well-distributed points, such as *A*, *B*, and *C*, which appear well located on the map.

(2) On the map, scale the distance 460 yards grid east from *A* to the nearest or most convenient Y-grid line, in this case 56. About *A* on the photograph, strike an arc to the eastward with a radius of 460 yards to the scale of the photograph.

(3) Repeat this for point *B*. The radius here is 225 yards in the same direction.

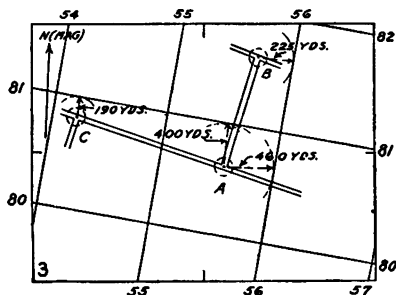


FIGURE 47.—Method of superimposing the military grid on an aerial photograph.

(4) Strike in with a straightedge Y-grid line 56 on the photograph tangent to the arcs about *A* and *B* and number it accordingly. This serves as the base Y-grid line.

(5) Draw in the remaining Y-grid lines which fall on the photograph parallel to Y-grid line 56 and 1,000 yards (or any other grid interval selected) apart to the scale of the photograph.

(6) In similar manner scale from the map in yards the distance grid north from *A* and *C* to the X-grid line 81 which is nearest *A*. These values are 400 yards and 190 yards, respectively.

(7) At *A* and *C*, in turn, on the photograph strike off to northward arcs whose radii are 400 yards and 190 yards, re-

spectively, and draw the base grid line 81 through to these arcs.

(8) Draw in the remaining X-grid lines parallel to this at intervals of 1,000 yards to the scale of the photograph.

(9) Finally number all grid lines properly and indicate magnetic north. Compare photograph grid to map grid critically for any discrepancies which clearly cannot be attributed to relief or tilt displacements.

(10) To reproduce in quantity, draw the grid in with black ink and rephotograph; or fit the film to back of photograph over an illuminated glass plate, carefully register, cut the grid through the film coating with a stylus, and print from the original film.

(11) While three points such as *A*, *B*, and *C* are preferable, two points as *A* and *B* would suffice for transferring the grid. In this case the procedure for establishing the 56 Y-grid base line is the same, but the 81 X-grid line is established by drawing line 81 tangent to its arc about *A* (400 yards) and intersecting *Y* at line 56 at right angles.

(12) The grid may be superimposed roughly by drawing the lines on the photograph through images which correspond to objects or features through which the grid lines on the map pass.

b. Local grid.—In order to superimpose the military grid on a photograph or mosaic of unmapped terrain it is necessary to know the geographic coordinates of at least two points of the same longitude for each sheet. When it is impractical to secure this information, a convenient rectangular local grid is used in lieu of the military grid. All copies of the mosaic in local use must be similarly equipped in order for the local grid to serve its purpose.

c. Inch grid (fig. 48).—The inch grid is a local grid affording simple, quick, and accurate means of locating points and features on photographic prints. Photographs issued in the form of photo-maps bear this grid registered on the neat lines of the photograph along the four sides. The origin of the grid is the lower left-hand corner of the photograph when held with the direction of flight (indicated by an arrow) upward. The coordinate scale is used on the photograph in the same general manner as the coordinate scale used on the map with the ex-

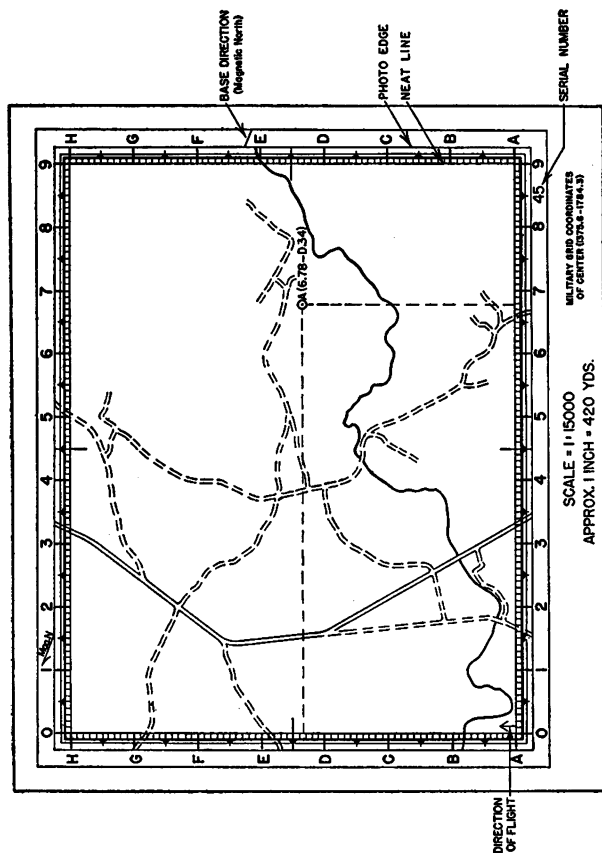


Figure 48.—A photograph with marginal data consisting of scale, magnetic north, the military grid coordinates of the center, and the inch grid added to form a photo-map.

ception that Y coordinates are expressed in letters of the alphabet in lieu of numerals. The coordinates of a point are expressed in units, tenths, and hundredths of inches. The X coordinate expressed by a numeral is written first followed by the Y coordinate expressed by a letter, the whole being enclosed in parentheses. Thus the inch-grid coordinates of the point A are (6.78-D.34), indicating that it is 6.78 inches to the right of and 3.34 inches above the origin at the lower left-hand corner of the photo-map.





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